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Circular No. 583

Eggs and Egg Products

A Publication by Poultry and Egg Specialists
of the United States Department
of Agriculture

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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C., JANUARY 1941

STATEMENT OF COOPERATION

This circular was planned by the United States Department of Agriculture Poultry Committee, appointed by Secretary of Agriculture Henry A. Wallace to coordinate activities of the Department having to do with poultry and to provide information on poultry and poultry products. The membership of the committee includes representatives of units active in phases of poultry production, utilization, or marketing.

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Circular No. 583
January 1941 • Washington, D. C.
UNITED STATES DEPARTMENT OF AGRICULTURE

Eggs and Egg Products

A Publication by Poultry and Egg Specialists of the United States Department of Agriculture[1]

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[1] Prepared by direction of the United States Department of Agriculture Poultry Committee. Edited by Roy E. Miller, Division of Publications, Office of Information.

INTRODUCTION

Egg consumption in the United States is relatively large. Aggregate utilization, of which human consumption accounts for more than 90 percent, in many years exceeds 300 eggs per capita. The quantities of eggs consumed surpass in weight those of most other foods, exceptions being milk, meat, potatoes, and flour products. Rich in food elements and protective qualities and low in heat production, eggs are frequently called the perfect food. In money value they rank about fifth among the foods, their cost being nearly 5 percent of the total cost of food for the average family.

Increase in use of eggs as a food and advance in maintenance of egg quality have kept pace for decades. The reasonable cost of production and distribution, usually prevailing, has helped to bring about the increase in consumption. Almost daily use of eggs is a well-established food habit.

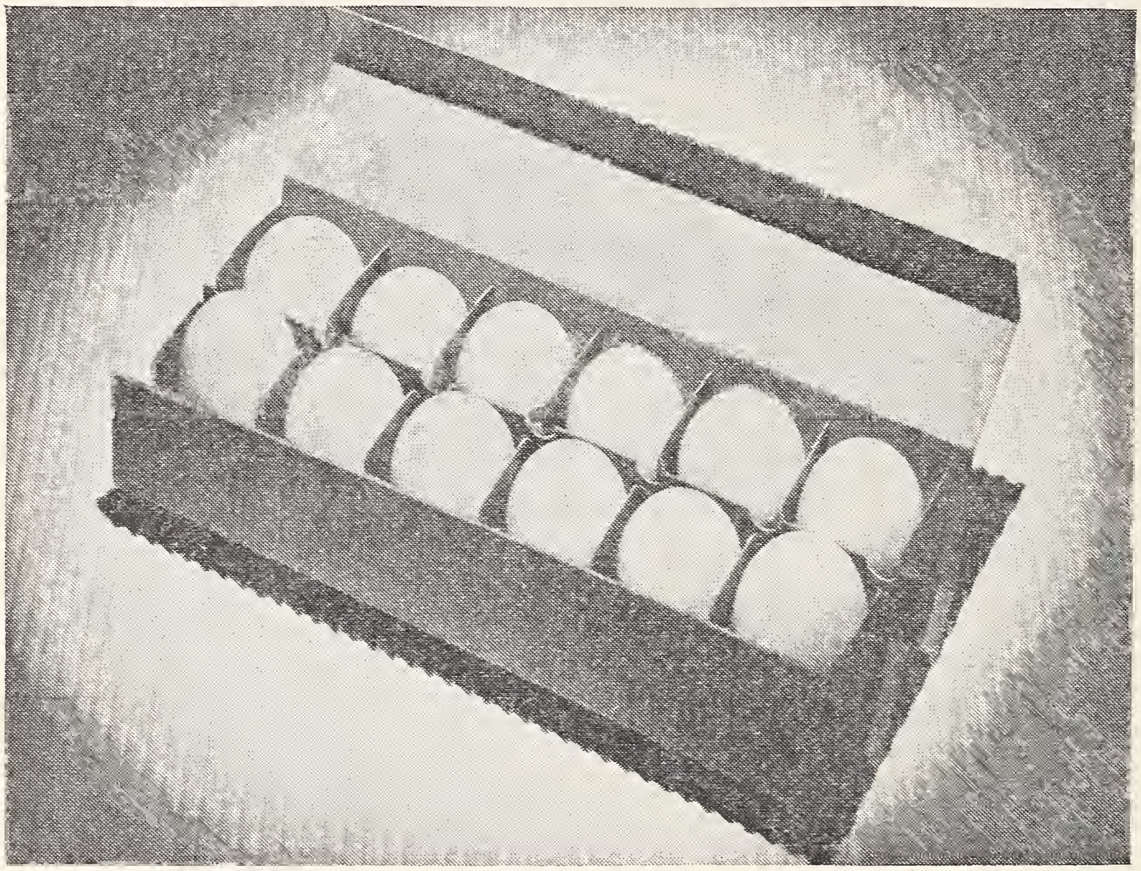

FIGURE 1.—Value of eggs depends on interior quality and exterior appearance.

Recent surveys show that families buy larger quantities of eggs as their incomes permit increased spending for food. In some centers of population it has been found that families with ample income consume practically twice as many eggs as families in the lower income groups.

Less than 1 percent of the chicken eggs consumed in the Nation are imported; the rest are of domestic production, nine-tenths of which is on the farms. Annual farm production from 1935 to 1939 ranged from 33 billions to 38½ billions of eggs, about 3 billion dozens a year. The farm income from eggs is estimated to average

600 million dollars a year. Egg production, handling, and marketing furnish employment in numerous occupations in all the States.

The market value of eggs at any one time depends largely on their interior quality and exterior appearance (fig. 1). Grading of eggs follows definite standards, and the higher the standard, other things being equal, the better prices the eggs will bring. In grading to these standards, the size, shape, and weight of eggs and the soundness and cleanness of their shells are given due consideration, but the most important factor is interior quality. To maintain the original quality as long as possible in so perishable a product requires great precaution in caring for eggs on the farm and through all the steps necessary to bring them to the consumer.

The growing consciousness of egg quality on the part of the consumer and the degree of dependence of prices on the excellence of the goods have focused attention on many problems in producing, storing, handling, and marketing of eggs and egg products. Some of these problems are discussed in this circular.

EGGS AS A STAPLE COMMODITY[2]

Fragile as eggs are, they have long been a staple article of commerce and have helped the farmer purchase other needed foods and manufactured goods. More than 1,000 years ago, country people paid their taxes by supplying imperial households with eggs. Drying, pickling, and storage of eggs in various materials have been practiced for many centuries. It is only in the last 50 years, however, that selection, packing, transportation, and cold storage have been perfected to a degree warranting development of the egg trade into a commercial enterprise of the first rank.

Handling eggs involves all the time and resources of many establishments and part of the activities of thousands of others, from the great poultry- and egg-packing houses and storage plants to the smallest retail stores. Farmers in the United States have sold more than half a billion dollars' worth of eggs annually for many years. About 300 million dollars in addition has been received annually by buyers, shippers, packers, processors, various dealers, and retailers in distributing eggs to the consumer.

The number of chickens on farms at the beginning of 1940 was 429 million. Increases in 1938 and 1939 practically made up for the losses of layers in the drought years. Producers in 1939 sold well over 2 billion dozen eggs, chiefly for cash. Farm households consumed about 22 percent of the eggs produced.

DISTRIBUTION OF EGGS

The city demand, which absorbs about three-fourths of the eggs produced in the entire country, is chiefly responsible for the development of a vast system of distribution (fig. 2). It would take long trains of wagons or trucks, or more than 80 freight cars, to move a million dozen eggs, just enough to supply 2 or 3 of the largest cities for a single day. Thousands of scattered receiving stations, stores, and assembling plants are required to care for some 6 million dozen eggs entering commerce daily.

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[2] By C. C. Warren, associate agricultural economist, Poultry Division, Surplus Marketing Administration; charts contributed by R. J. Foote, assistant agricultural statistician, Bureau of Agricultural Economics.

Assembling, grading, storage, and transportation of eggs, in view of the perishability of the goods, are relatively expensive, the marketing system complex. Considerable quantities of eggs are sold by the farmer directly to the consumer, the huckster, or the country store; those produced close to the principal markets are delivered in large measure directly to the wholesaler or retailer; but most of the eggs on the market go through the customary stages of commercial handling.

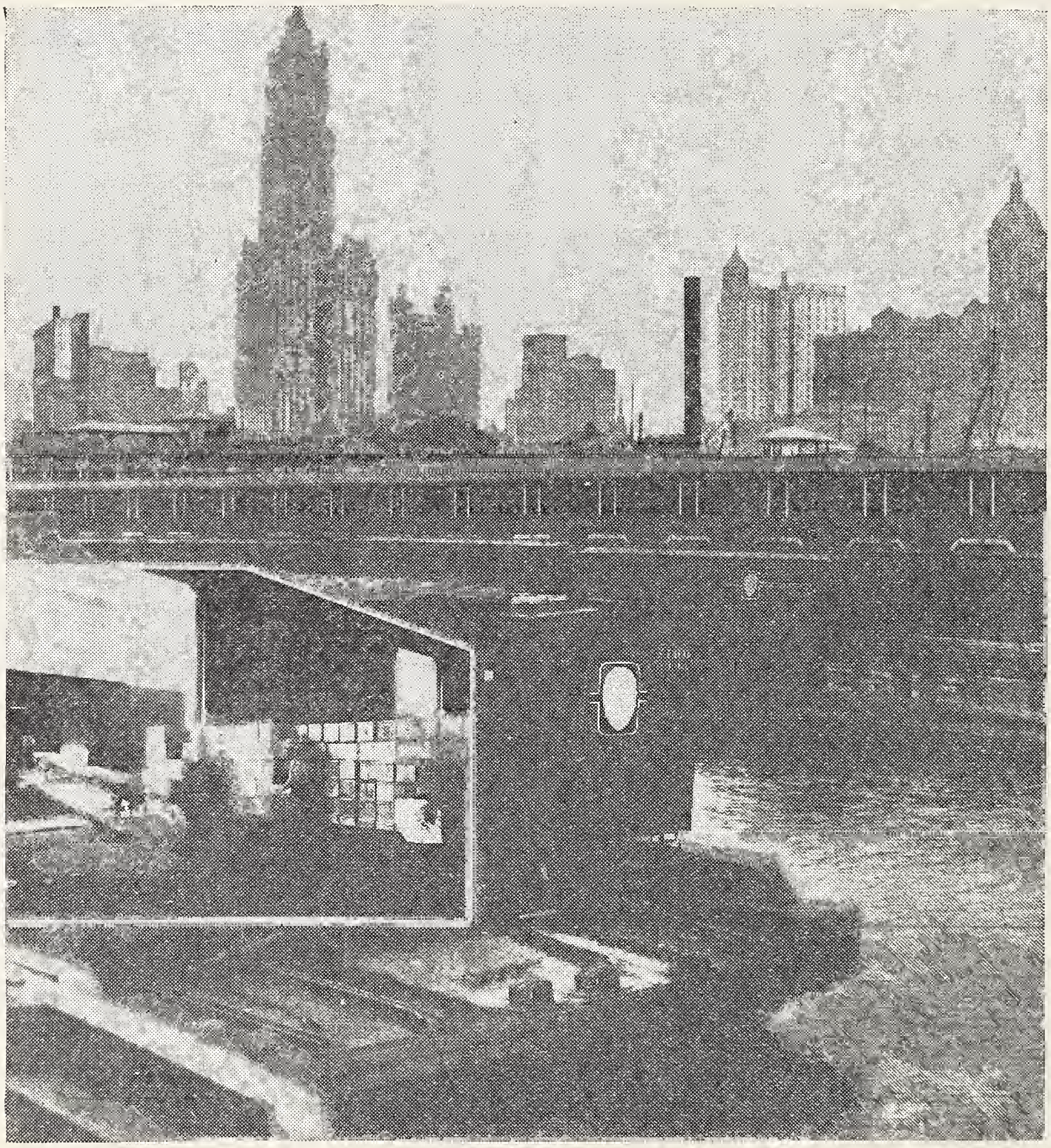

FIGURE 2.—City dwellers consume about three-fourths of the eggs produced in the United States. The best facilities for packing, transportation, storage, and merchandising are necessary to carry eggs to consumers.

Receiving, packing, storage, and egg-products plants, houses selling cases and fillers and other supplies, and transportation companies, brokerage firms, and financing agencies perform essential services for the industry. Shippers, packers, jobbers, or others may store eggs to fill expected orders. Producers and suppliers of feeds and equipment, users of egg products in baking, and many others share in some measure in the commerce of eggs.

Most farms still produce eggs largely on a seasonal basis. Facilities for off-season production require attention that many farmers are unable to give; the henneries therefore get much of the direct trade. Time and distance from market add to the cost of marketing and subtract from the net returns to producers. Without highly specialized storage and transport, the marketing of the bulk of the eggs now produced on farms (table 1) would be impossible.

Table 1.—*Eggs produced on farms in the United States in 1934, by size of flock*

Size of flock (number)	Total eggs produced	Percentage of total production	Eggs produced per farm
	1,000 dozens	*Percent*	*Dozens*
Under 50	376, 397	17. 4	117
50–99	432, 284	20. 0	341
100–199	570, 997	26. 4	724
200–399	393, 982	18. 2	1, 552
400–699	154, 305	7. 2	3, 686
700–999	64, 851	3. 0	6, 722
1,000–2,499	115, 525	5. 4	12, 139
2,500 and over	52, 565	2. 4	35, 541
Total	2, 160, 906	100. 0	387

Bureau of the Census.

The usual farm flock contains only 60 to 70 layers. Yet to the farmer eggs are one of the few everyday cash crops, and egg production is often one of the largest sources of income (fig. 3). To certain industries and to many prepared-food manufacturers eggs are a staple raw product, much as wheat is to the mill or fruit is to the cannery.

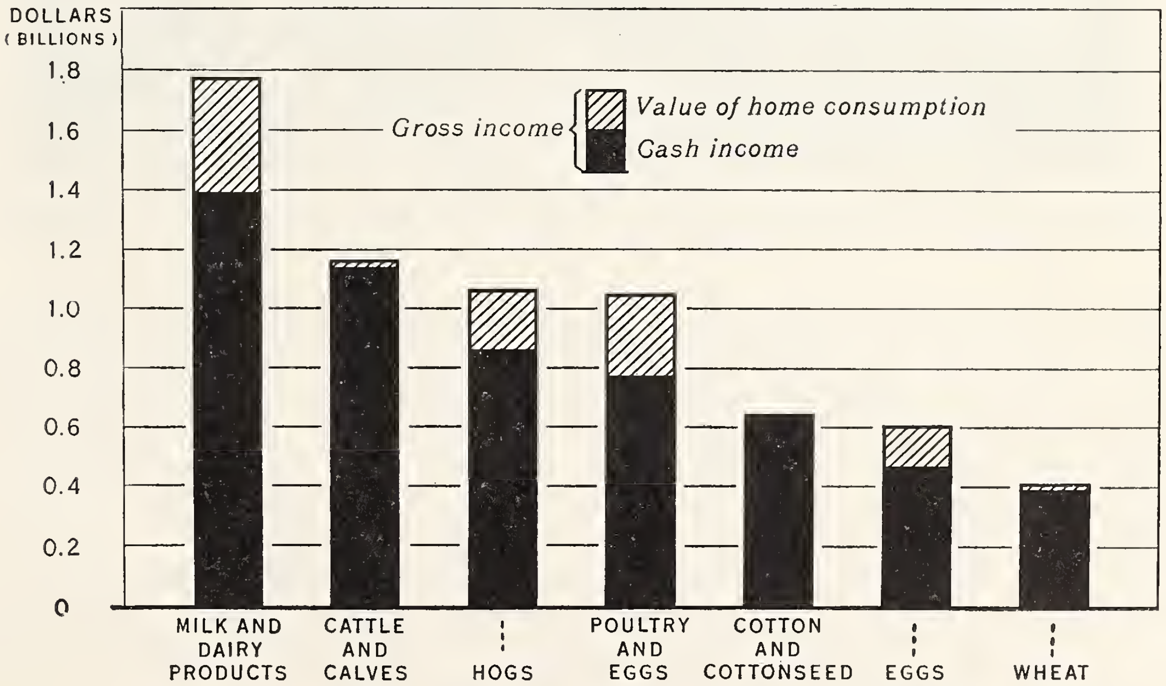

Figure 3.—Cash and gross farm income, selected farm products or groups of products, United States, 1938. Eggs are among the leading sources of farm income. Other individual items brought in less income than those shown.

They are sold in innumerable stores. A highly complex marketing machinery has developed to convey eggs and egg products in constant supply to the consumer.

Principal Uses of Eggs

According to a survey made by the Agricultural Adjustment Administration,[3] 91 percent of all eggs are utilized directly from the shell. Liquid and frozen eggs, used mostly in the baking and confectionery industries, account for about 7 percent of all eggs (fig. 4). Dried-egg products, also used by bakeries and confectioneries as well as by other food factories, amount to over 1½ percent of all eggs consumed. The egg-freezing industry during the last 20 years has undergone rapid development to meet the demand on the part of consumers for prepared foods, particularly bakery products. The egg-drying industry in this country has also been expanding, partly because of unsettled conditions in China, which in the past has been the major source of supply. The extent of utilization of eggs for various domestic and commercial purposes is given in table 2.

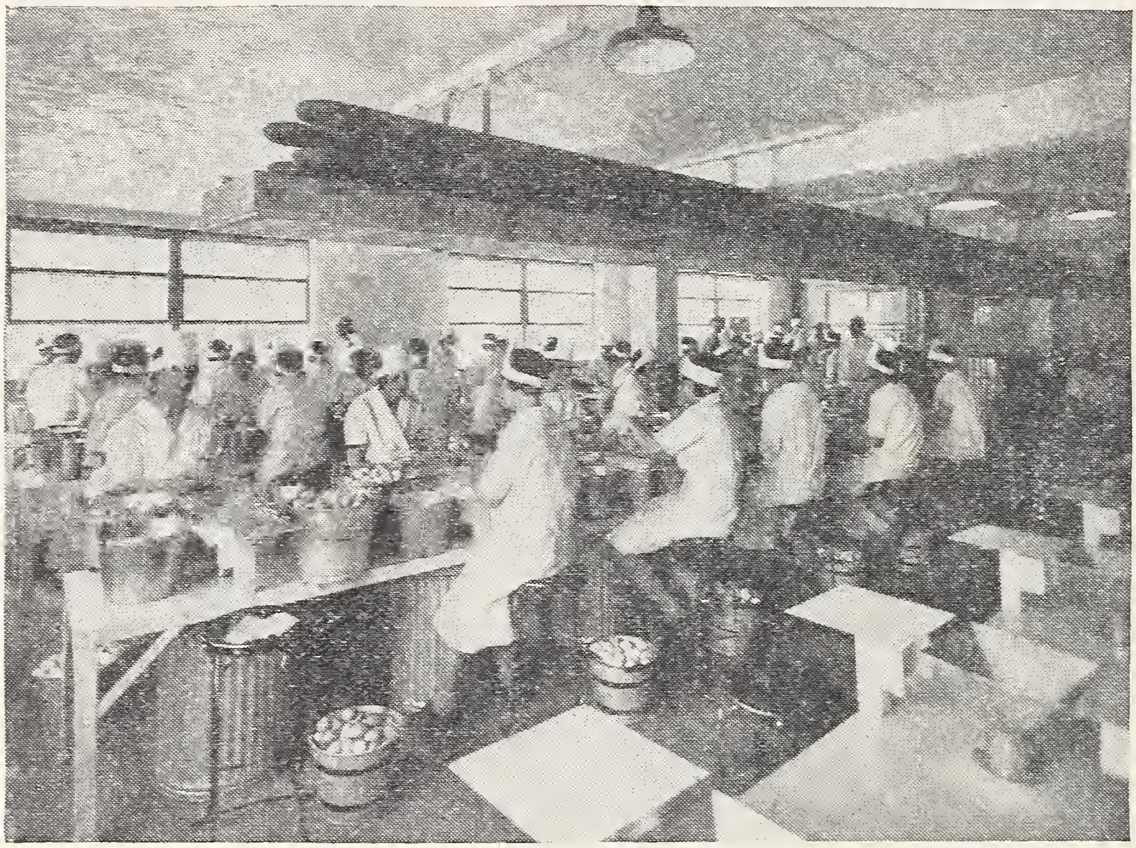

Figure 4.—Interior of a breaking plant in a heavy-production area. Trained egg breakers work under sanitary conditions in an air-conditioned room.

Nearly 5 percent of the eggs produced are wasted because of mishandling either on the farm or while en route to the consumer, the waste representing a huge annual loss to the poultry industry. Under careful management, it could be greatly reduced.

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[3] Radabaugh, J. H. production of frozen eggs in the united states in 1937 (with comparisons to 1935 production). U. S. Agr. Adjustment Admin., Poultry Sect., 10 pp. illus. [n. d.] [Mimeographed.]

TABLE 2.—*Utilization of eggs in the United States*

Use	Shell eggs	Liquid and frozen eggs					Dried eggs			All eggs	
		Whole or mixed	Whites	Plain yolks	Yolks processed with salt	Yolks processed with sugar or glycerin	Whole	Whites	Yolks	Quantity	Percentage
	1,000 Dozen	*1,000 Dozen*	*1,000 Dozen*	*1,000 Dozen*	*1,000 Dozen*	*1,000 Dozen*	*1,000 Dozen*	*1,000 Dozen*	*1,000 Dozen*	*1,000 Dozen*	
Table use	2,132,000	------	------	400	------	700	------	------	------	2,133,100	80.46
Noodles	------	2,000	------	4,800	------	------	34	------	2,344	9,178	.35
Bakery products	20,000	86,000	37,000	7,100	------	10,000	630	326	18,358	179,414	6.77
Salad dressings	------	3,000	------	2,200	2,500	400	------	------	------	8,100	.31
Mayonnaise	------	------	------	6,600	7,500	1,500	8	------	1,562	17,170	.65
Ice cream, etc	------	2,000	1,000	700	------	1,400	8	------	11,718	16,826	.63
Confectionery	------	------	10,000	------	------	------	------	1,050	------	11,050	.42
Prepared flour	------	------	------	------	------	------	84	42	3,906	4,032	.15
Food-beverage products	------	------	------	------	------	------	25	------	391	416	.02
Prepared puddings and meringues	------	------	------	------	------	------	17	347	391	755	.03
Bird and animal food, etc	------	------	------	------	------	------	34	------	------	34	------
Pharmaceutical and photographic	------	------	------	------	------	------	------	42	------	42	------
Industrial	6,850	------	------	------	------	------	------	295	------	7,145	.27
Hatching	113,000	------	------	------	------	------	------	------	------	113,000	4.26
Other uses	20,000	------	------	200	------	------	------	------	391	20,591	.77
Losses (rots, broken, etc.)	130,150	------	------	------	------	------	------	------	------	130,150	4.91
Total	2,422,000	93,000	48,000	22,000	10,000	14,000	840	2,102	39,061	2,651,003	100.00
Percent of all eggs	91.36	3.51	1.81	.83	.38	.52	.03	.08	1.48	100	------

[1] Based on 1935 estimates by the Agricultural Adjustment Administration.

Normally 4 to 5 percent of the annual egg production is used for hatching purposes, both for flock replacement and meat production. Most hatcheries are found in regions of heavy egg production. Therefore, to some extent, hatcheries compete for eggs with the normal channels used for marketing fresh eggs and with the cold-storage packer. In the spring months many egg producers sell high-quality hatching eggs to hatcheries and obtain a substantial premium over the market prices for eggs sold for food. These premiums vary greatly with the locality, ranging usually from 5 to 15 cents or more a dozen—in the aggregate, a farm income of several million dollars a year.

Of late years there has been a significant trend toward early hatching of baby chicks in January and February in order to obtain mature pullets for fall layers. This early hatching is having an influence on the marketing of eggs, in that a scarcity of fresh eggs in the fall, on a scale of several years ago, no longer exists. This situation tends to prevent egg producers from receiving as high prices as formerly prevailed in the fall and winter months. Some hatcheries also continue their activity in the "off season" in order to serve those engaged in the year-round production of broilers. In addition, many commercial-flock owners buy baby chicks in the fall in order to replace losses from death and culling that occur in the laying houses in winter. Both of these comparatively new practices tend to limit to an appreciable extent the need for storage of great quantities of eggs in the spring for consumption in the fall and winter.

Packaging and Transporting Shell Eggs

Since all eggs go to the primary markets in the shell and the bulk of them arrive at the consumer's kitchen in this natural container, the contents of the egg is one of the few foods which reach the consumer untouched by human hands. Shipments may be made in special packages, but generally the producers, shippers, and packers use the standard 30-dozen case, built to specifications and fabricated from knock-down parts at the packing house. This type of egg case, which long ago succeeded the barrel of oats, has stood the test of time. Even railway cars have been adapted to some extent to handle the standard carlot of 400 cases.

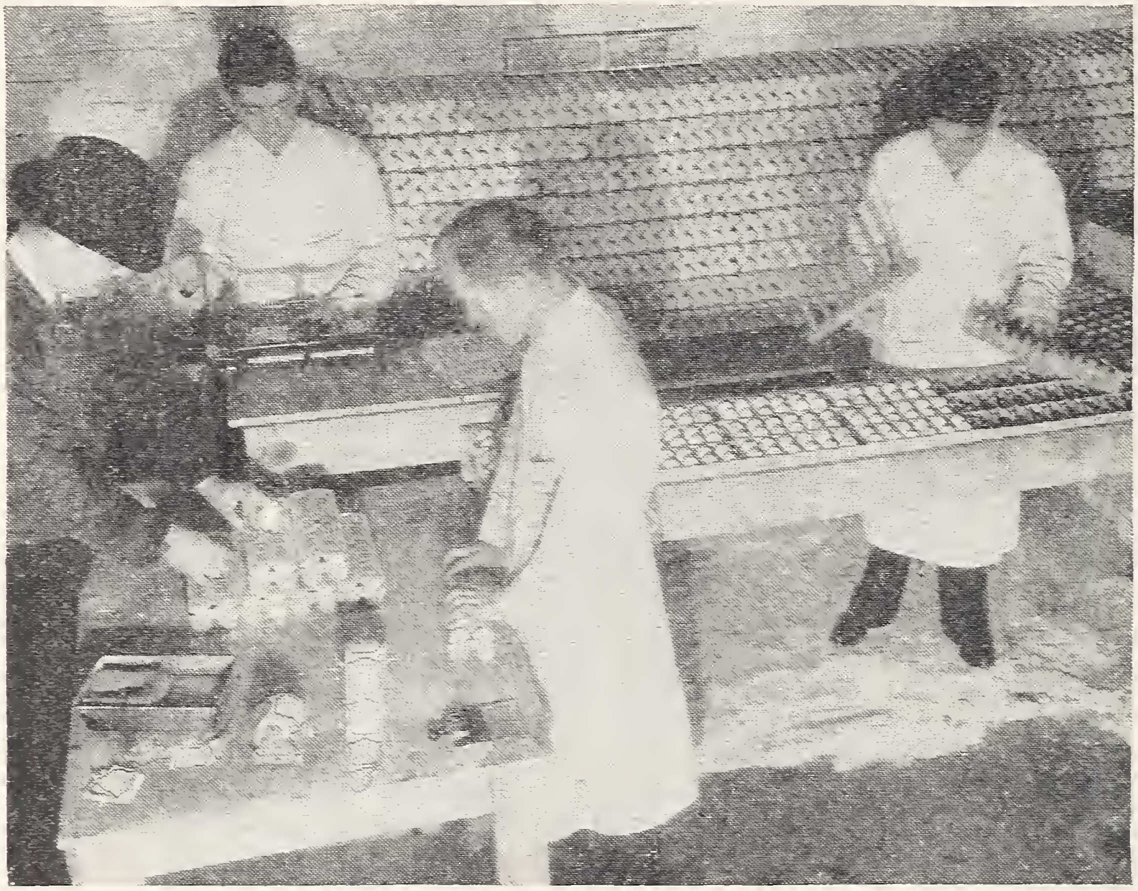


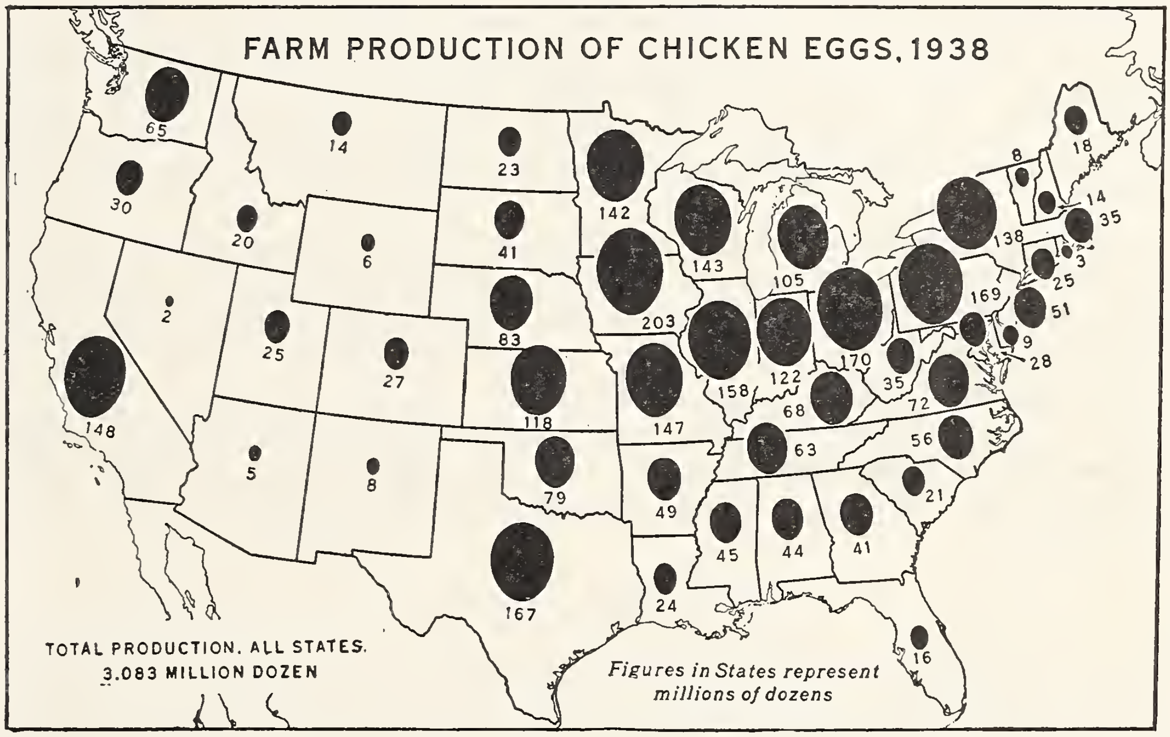
Figure 5.—Cartoning eggs for retail market. Man at left is attaching certificate of quality and grade.

Improvements have been made, through studies by the Forest Products Laboratory, of the Forest Service, in increasing rigidity of cases by proper nailing and in the use of various woods available for this purpose. Flats, pads, and better fillers have been designed to prevent as far as possible breakage, absorption of bad odors, and the growth of molds. Well-packed cases and small containers can be sent to consumers by parcel post or express. Half-case-size fiber containers are growing in favor with small retailers who keep supplies fresh by frequent purchases.

In retail establishments use of 1-dozen-egg cartons has become common. They are designed to pack snugly in the standard egg case. In some large distribution centers, eggs are transferred from standard-packed cases to retail cartons (fig. 5). Such transfer may result in accumulation of a large number of second-hand fillers and cases that present a problem to the transportation companies and are likely to cause spoilage when used again. Use of the 1-dozen carton, however, facilitates handling and certification, and the storekeeper finds it easy to place the cartoned eggs in a refrigerator and to remove the cartons readily for delivery to the customer.

Transportation of eggs is a large item in the operation of railroads, which in 1938 carried 30,828 full cars of eggs,[4] equivalent to a freight train 308 miles long. These eggs weighed more than 355,000 tons, and revenue to the railroads amounted to $6,475,000. Large quantities also were moved in less than carlots and by truck.

Local assembling of eggs in facilitated by use of motortrucks, some of them air-conditioned; larger shipments usually are precooled and shipped in refrigerator cars. A large proportion of the eggs produced, however, arrive without precooling or other special care at country and village stores. This necessitates expensive transfer and candling later at properly equipped receiving plants and causes losses from spoilage and lowered grades.


FARM PRODUCTION OF CHICKEN EGGS, 1938

TOTAL PRODUCTION, ALL STATES, 3,083 MILLION DOZEN

Figures in States represent millions of dozens

FIGURE 6.—Egg production by States.

The geographical location of major producing sections (fig. 6) and the concentration of population in industrial regions further complicate the problems of commerce in eggs and egg products. Factors of climate and commercial opportunity also enter into the development of the poultry and egg industries. Because feed is the largest item of cost in producing eggs,[5] the extent and character of the feed supply often determine the scale of regional and local egg production.

The cooperation of Federal and State experiment stations and other agencies, which have published the results of many studies on feeding, breeding, and housing of laying flocks and care of eggs, has encouraged development of poultry enterprises in all sections of the country. Information of current value to producers and handlers of eggs is issued in frequent, regular reports on production and marketing conditions by the Agricultural Marketing Service of the United States Department of Agriculture. Many of these specialized statements, together with a summary, are given in the mid-month mimeographed report, Poultry and Egg Production. On the 20th of each month the Bureau of Agricultural Economics issues the Poultry and Egg Situation, which contains discussions of the significance of changes in the situation for poultry and eggs during the past month as they affect the production and price outlook.

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[4] Data from Interstate Commerce Commission.

[5] General production problems, costs, and market prices are subjects largely outside the range of this circular.

Financing the Industry

In the commercial handling of eggs distributors finance the various steps in handling from the time of receipt until the eggs reach the consumer. This responsibility generally involves the use of large funds. The distributors must also be prepared for some losses, which may include market declines and credit losses as well as deterioration of goods.

The farmer finances production costs, including housing and maintenance. Like the distributor, he depends to some extent on the bank; but current expenses and replacements are largely taken care of by the sale of eggs.

Farmers' cooperative egg auctions are eligible for loans from the Bank for Cooperatives, operating under supervision of the Farm Credit Administration. Eggs are acceptable as security for commodity loans. Adequate credit facilitates orderly marketing by farm cooperatives.

TRADING IN FUTURES

A special market activity of the Federal Government is the supervision of trading in egg futures. Trading in egg futures was begun on the Chicago Mercantile Exchange in 1919 and on the New York Mercantile Exchange in 1924. Its sponsors believed that it would serve a useful economic function by furnishing hedging facilities to distributors and dealers, by maintaining a continuous liquid market, and by giving frequent price quotations. Futures trading has developed rather steadily and averages approximately 40,000 carlots, or 515 million dozen eggs a year, having an approximate value of 125 million dollars.

The volume of futures transactions is approximately one-fifth of production. It slightly exceeds egg receipts at the five principal spot markets and is nearly double the average annual cold-storage holdings of eggs. During the 7 years 1933–39, the volume of trading in egg futures followed a definite seasonal pattern. The smallest monthly volume of trading always occurred during the first 3 months of the year, when the number of eggs in storage is small; whereas the largest volume of trading always occurred during the last half of the year, when the number of eggs in storage is large. The seasonal pattern of the volume of futures trading corresponds to the seasonal pattern of eggs placed in storage. The reason for this fact is two-fold: (1) Much of the purchasing of futures contracts is for the purpose of obtaining the eggs for storage purposes, and (2) as dealers put eggs in storage they hedge them in the futures market in order that they may be unconcerned about price changes and free to concentrate on merchandising profits.

Because of the close relationship between cash and futures prices and the necessity for preventing manipulation or other improper influences to affect egg prices, the Federal Government supervises all transactions on the futures exchanges.

Scope of Research

Poultry experimentation is one of the important fields covered by the programs of research of the State agricultural experiment stations and the United States Department of Agriculture. Industry cooperates in some of the studies. The Office of Experiment Stations of the United States Department of Agriculture is charged with administering grants of Federal funds to States and Territories for agricultural research, which includes among other subjects poultry research; coordinating Department research internally and with research of State and Territorial experiment stations; and administering the special research fund of the Department.

Studies of egg production, grading, marketing, and other phases of the industry were included in more than 170 approved poultry projects carried on by State stations in 1938–39. Findings of the stations are made readily available to the public through press articles, addresses, and State and Federal publications.

CARE OF EGGS ON THE FARM[6]

Normally the hen lays a good egg. The quality of eggs may be improved, however, by selecting breeding birds that produce eggs weighing 24 ounces or more to the dozen and by proper feeding. Keeping eggs clean and maintaining internal good quality are responsibilities of the farmer, the egg dealer, and other handlers including the retail storekeeper. The farmer in particular has an excellent opportunity to profit by good care of eggs.

Keeping Eggs Clean

Studies have shown that more than 99 percent of all eggs are clean before they come in contact with the nest. Certain types of nesting material are effective in preventing dirty eggs. Highly recommended materials are shavings, oat hulls, sawdust, and excelsior.[7] Straw has characteristics which make it one of the best nesting materials, and it is used extensively on many farms, although it does not rank so high as the other materials mentioned. If straw is used, care must be taken to see that it is clean, dry, and free from molds.

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[6] By H. L. Shrader, senior extension poultry husbandman, Extension Service, and Animal Husbandry Division, Bureau of Animal Industry.

[7] FUNK, E. M. FACTORS INFLUENCING PRODUCTION OF CLEAN EGGS. Mo. Agr. Expt. Sta. Bul. 384, 12 pp., illus. 1937.

Providing a sufficient number of nests is also important. The usual ratio is one nest for every five hens. Keeping the nests darkened helps to prevent crowding. Frequent gathering of the eggs reduces the number of dirty eggs sometimes as much as 50 percent. A common practice on well-operated commercial egg farms is to gather eggs three times a day—at 10 a. m., 2 p. m., and 5 p. m. The management factors that promote clean eggs include keeping deep litter on the floor of the poultry house, proper feeding, and keeping the birds confined to the house, at least until noon.

Cleaning soiled eggs is a difficult task. It is not a good plan to wash eggs in plain water, as this procedure destroys the protective covering on the shells (fig. 12). The keeping quality of eggs washed in such manner is much poorer than that of eggs not washed. Washing leaves the pores of eggshells open, permitting bacteria to enter, and although the outside of the shells may appear cleaner, the inside of the eggs may be affected.

Recent tests of cleaning methods indicate that eggs carefully washed with lye water can be held in storage satisfactorily. A 1-percent solution of sodium hydroxide (common lye) is used. Apparently, lye water does not affect the flavor of eggs, but unless the solution is of the proper strength the keeping quality of the washed eggs will be impaired. It is possible to wash eggs either on the farm or at the receiving plant, and cleaning of eggs to be held long should be done without much delay.

In handling the powdered lye, mixing and using the solution, and cleaning up, care must be taken to prevent the powder or solution from touching any part of the body, particularly the eyes, or the clothing. Goggles which completely enclose the eyes and have indirect ventilation should be worn. Rubber gloves and rubber aprons should be used to protect the hands and clothing. Lye should not be stored where other materials in similar cans are stored or where children have access to it. It is suggested for complete protection that only sufficient quantities for immediate use be purchased.

The eggs are washed thoroughly and placed on wire trays to drain and dry. The solution requires frequent changing to keep it at proper strength. Dirty eggs, whether they are to be sold on local retail markets, shipped, stored in the shell, or broken out and stored as a frozen product, may be benefited by washing in lye water. Managers of egg-breaking plants find that washing dirty eggs in this lye-water solution helps to keep the bacterial count of the liquid eggs at a lower level.

Eggs may be cleaned fairly well on the farm by removing a dirty spot with a damp cloth or by buffing with emery cloth or steel wool, although steel wool is likely to leave marks. Sand-scouring machines for cleaning eggs have been used with good results in commercial packing plants. Some of these machines combine the use of rubber rollers and moist sand.

It is estimated that dirty eggs aggregate one-fifth or more of the total production. If the reduction in market value is about $1.25 per case, the loss to the farmers is many millions of dollars. The marketing of dirty eggs also has a depressing effect on consumer demand.

KEEPING EGGS COOL

GATHERING AND COOLING

Cooling to a safe temperature is an important factor in the care of eggs on the farm (fig. 7). The germ in fertile eggs can grow when the temperature is above approximately 68° F. Eggs when laid are about the temperature of the hen's body, 104° to 107°; therefore, prompt cooling is essential.

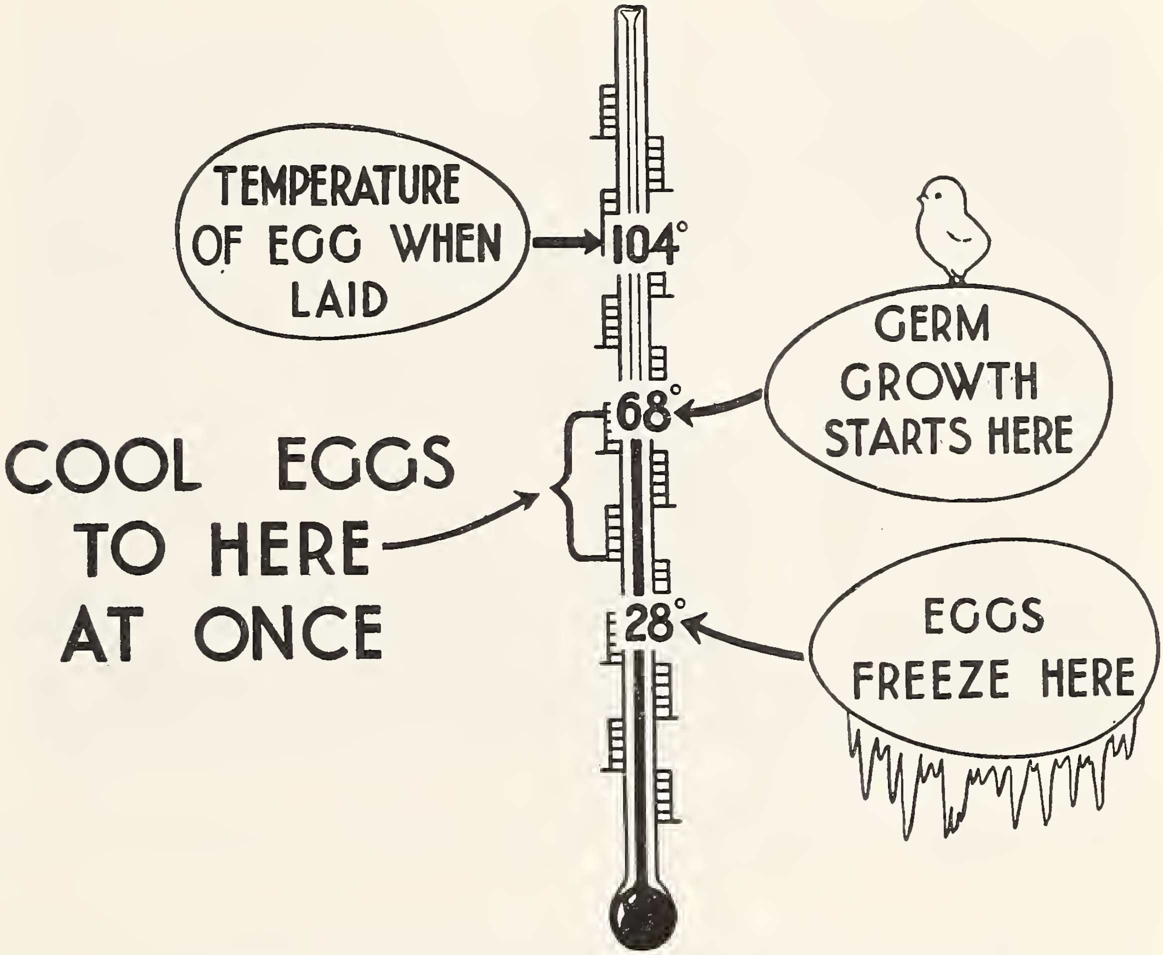

FIGURE 7.—Critical temperatures of eggs in the shell.

For market purposes infertile eggs should be produced. This is accomplished by removing the male birds from the flock. These birds have no effect on the number of eggs a hen lays; therefore, unless the eggs are used for hatching, there is no reason for producing fertile eggs.

With infertile eggs also, cooling is important in order to maintain the quality of thick, firm white and strong, upstanding yolk that is normal for a freshly laid egg. Prompt removal of eggs from the nest to a cool room facilitates lowering the temperature. On the other hand, if eggs are not removed and other hens occupy the nests, these eggs may be kept near body temperature for several hours. Broody hens should be removed promptly to a separate coop. During the warm summer months, the temperature in the poultry house is often high enough to keep the eggs from cooling rapidly. In very warm climates, special care must be taken to cool eggs promptly. In cold climates they must be protected from freezing temperatures.

In arid regions, it is essential to supply moisture to cooling rooms to prevent the eggs from drying out excessively.

For cooling eggs, producers make use of cellars, springs, caves, ice houses, and numerous home-made cooling devices. A popular and inexpensive cooler is made by covering the sides and ends of a frame with coarse burlap and moistening this cloth by keeping one end of it in a pan of water placed on top of the frame. The eggs are kept inside this framework both in open trays and standard egg cases.

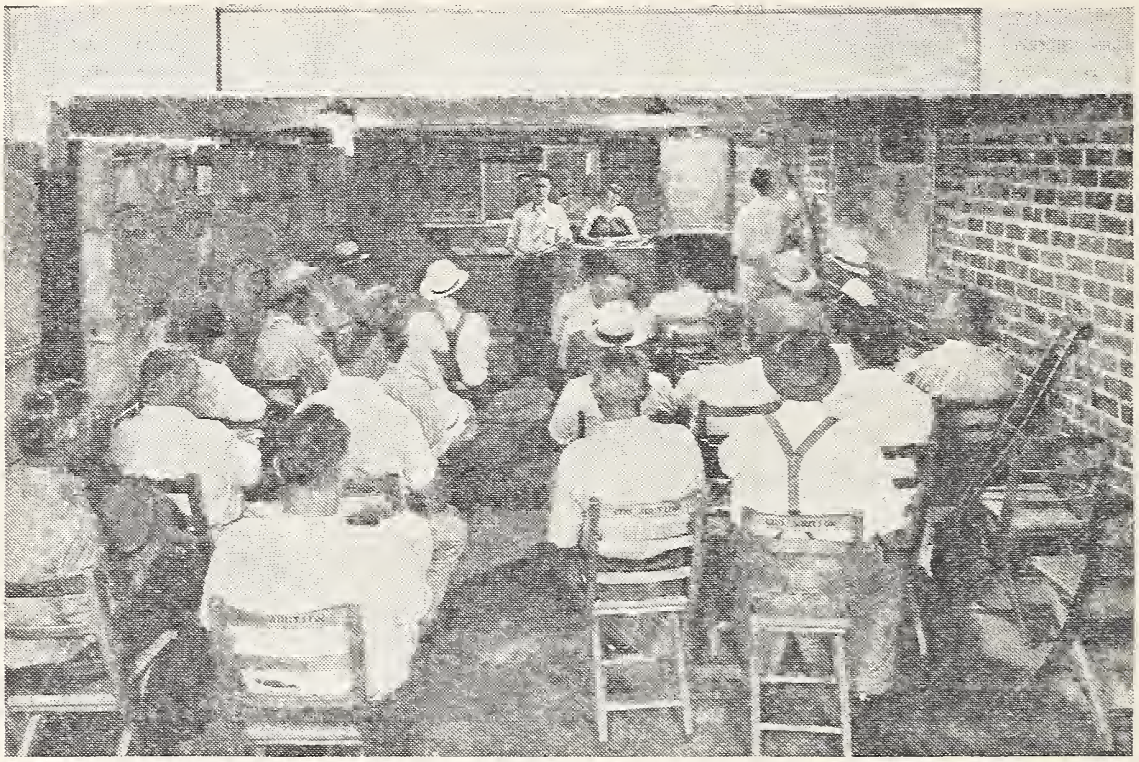

Figure 8.—Farmers' cooperative egg auction. Eggs are brought in, graded, and packed promptly. Buyers have the opportunity of bidding on stock of known good quality.

Recent advance in electric refrigeration and cooling has also been considerable. Refrigerators designed to meet the special needs of the farmer are becoming available. Some of these are built to accommodate a wire egg tray, as well as the cream container. Unprotected eggs lose moisture rapidly in an ordinary family refrigerator; for ideal conditions they should be placed in a fairly tight container or special chamber with cold walls.

The usual recommended temperature for egg-cooling rooms on the farm ranges from 40° to 55° F. Eggs should not be cooled to a temperature lower than 40° on the farm, because if they are later subjected to a comparatively high temperature in transportation, condensed moisture may form on the shells. This is commonly called sweating. The moisture removes the gelatinous bloom normally deposited on eggs, and the lack of bloom lowers the market value. Such eggs, with the pores in the shells opened, are likely to absorb undesirable odors, or they may become musty. A sound recommendation for handling farm eggs is to cool them as quickly as practicable and then to place them in the cases to be carried to market at the earliest opportunity. Warm eggs should never be placed in cases, for then they have no opportunity to cool rapidly.

Moisture in the cooling room is necessary to keep eggs from drying out and the contents from shrinking. It may be supplied by fine spray nozzles, melting ice, moist burlap hung about the room, or water poured on the floor if of concrete or other impervious material. For quick cooling, eggs should be spread out in a single layer, preferably on an open-mesh wire tray or table. Eggs in a full basket or a solid pail require reveral times as long to cool as do eggs in a single layer on a wire tray. Circulating the air around the wire containers speeds the cooling. Circulation of air is also important in preventing growth of mold if room humidity is high.

Farmers' cooperative auctions have stimulated better care of eggs on many farms and have maintained high standards of quality (fig. 8). Buyers at the auctions give a great deal of attention to interior condition, weight, and shell appearance of eggs. State departments of agriculture have assisted the cooperatives in improving temperature and humidity conditions in temporary storages. They also encourage frequent deliveries.

MAINTAINING PROPER TEMPERATURES DURING DELIVERY

Some cooperatives and private packers make it possible for the farmer to take his eggs from the cooler (fig. 9, *A*) and place them in a refrigerated truck for delivery to a refrigerated receiving plant. A large proportion of farm eggs are taken directly to egg and poultry shippers who are able to put them immediately into properly conditioned rooms, grade them, and pay the producer according to a quality grade. Millions of dozens of eggs are marketed this way every week.

Where there are no special facilities for transporting eggs to market, careful hauling will repay the producer. By whatever means they are transported, eggs should be carefully protected from rain, freezing temperatures, and especially from the warm sun. A simple covering, such as a tarpaulin thrown over the cases, usually serves well; sometimes a moistened but not dripping covering is helpful. Precautions against unnecessary jolting should also be taken.

Whenever top-quality eggs are delivered to the packing plant they must be placed at once in rooms of the right temperature and humidity, or they will deteriorate rapidly. It is impracticable for the buyer who does not have adequate storage facilities to buy eggs "on grade." The storekeeper who has neither storage nor grading facilities can seldom pay top prices, nor can he expect good prices when he forwards the eggs to the packing house. This loss of egg value is borne, in the long run, by the farmer. The lack of properly cooled and moisture-conditioned receiving rooms and covered motortrucks (fig. 9, *B*) is being remedied by many buyers to meet the competition of well-equipped concerns.

If the farmer depends on the sale of hatching eggs for part of his income, he should be prepared to keep them at fairly even low temperature (about 50° F.) and to deliver to the hatchery twice each week if possible.

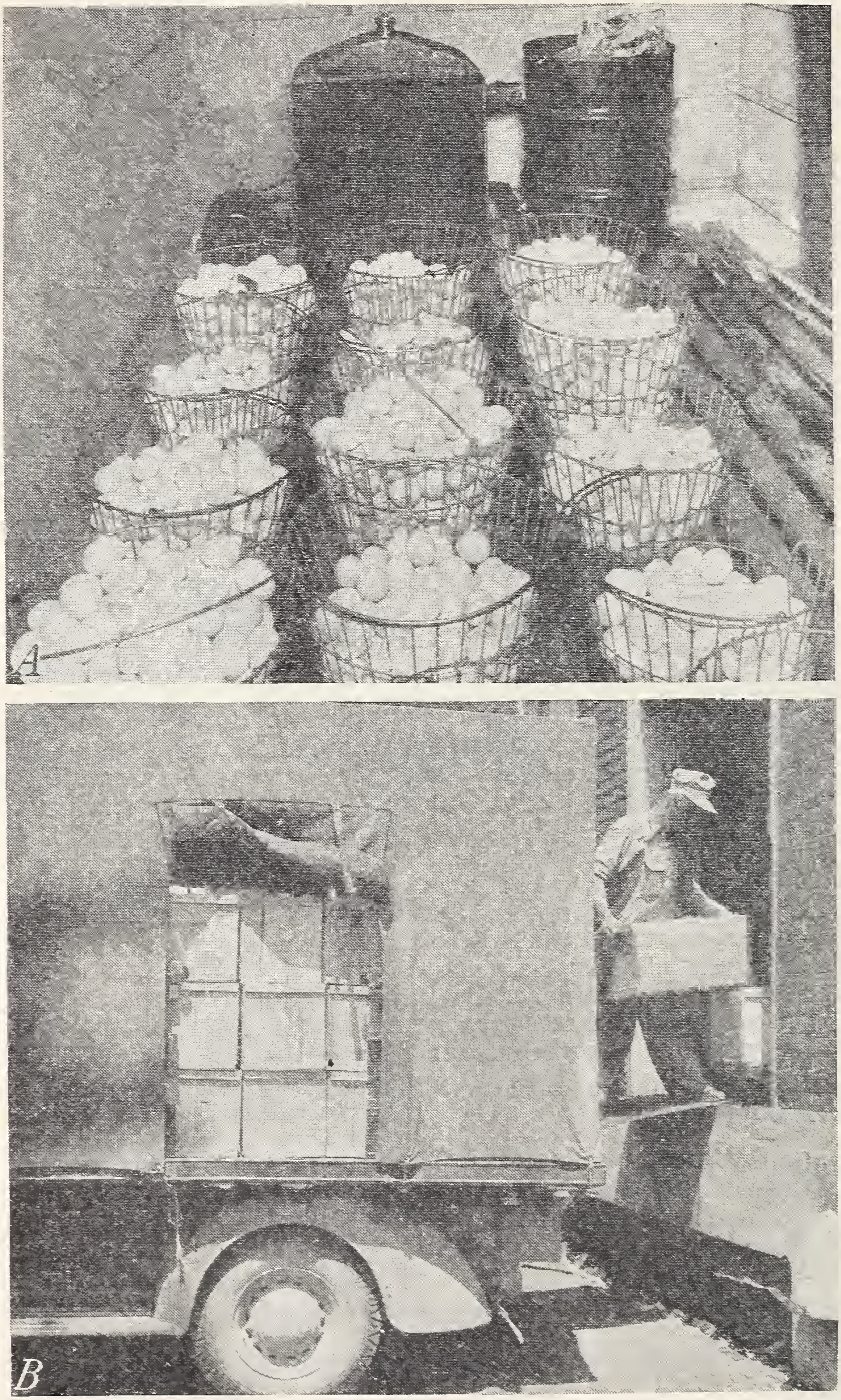

FIGURE 9.—Cooling and keeping eggs. *A*, Ice and motor-driven fans for cooling eggs and air-conditioned temporary storage room at a farm or a receiving plant; *B*, delivery to packing house from canvas-covered truck.

HANDLING EGGS FOR HATCHING

Eggs selected for hatching should be as far as possible of known fertility from hens of the breed desired and should be of uniform color, good size and shape, clean and unwashed, and sound of shell (fig. 10).

Hatching eggs must be carefully handled, and special packs may be provided for shipping. High-priced hatching eggs are sometimes shipped in excelsior-filled baskets with sewn cloth covers.

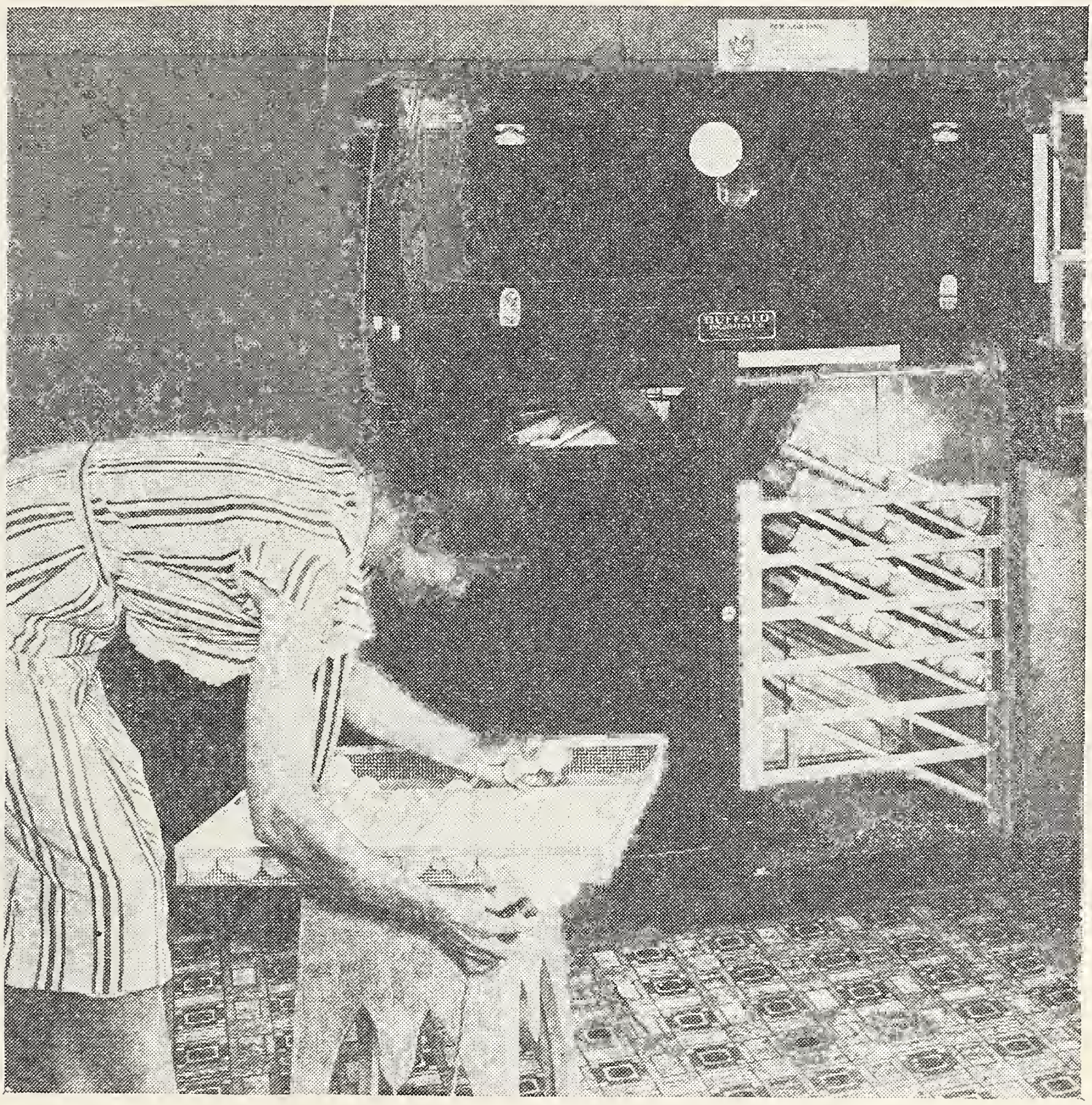

FIGURE 10.—Candling eggs for a small farm incubator. About 5 percent of all chicken eggs produced are used for hatching.

STORING AND PRESERVING EGGS FOR HOME USE

It is estimated that there are in the United States 3,000 freezer-locker plants, serving over half a million families in town and country. These consist of cold-storage rooms in which small compartments are rented on a yearly basis. They are held at near-zero temperature and are used to store meats, fruits, butter, and poultry products, the idea being to put such seasonal products into storage when they are plentiful and cheap and consume them later in the year. Eggs have been included in the list of commodities satisfactorily stored. The eggs are first broken out of the shell and placed in small tin containers.[8] This process is carried out in the spring months, when the price is lowest. In the fall and winter months the containers are removed, and the eggs are thawed out and used in the home as scrambled eggs or in cooking. Sometimes the egg yolks are separated from the whites, mixed thoroughly, and stored in separate containers, the housewife thereby having the ingredients for an angel-food cake or salad dressing all ready for mixing. This process of storing is only an adaptation of commercial practices, but it may be an important factor in promoting larger and more economical consumption.

Another refrigeration device used by farm groups, particularly in sections of the South, is a small chill room or "walk-in" cooler equipped with electric refrigeration. It may be erected as a separate building or placed in a country store. Ten to 20 families can keep their meat, eggs, and other perishables here, either for home use or for marketing. This large unit cools more cheaply than the family-size refrigerator. If it is placed in a store, the storekeeper usually operates the cooler for a share of the space. Care must be taken to prevent absorption of odors by the eggs, nor should they be chilled enough to make them sweat when removed for shipment.

From primitive times, people have packed eggs in ashes, clay, oats, salt, and other materials to keep them for home use. Fresh clean eggs may easily be preserved for later use at home by keeping them covered with a solution of water glass (sodium silicate). This solution is made by adding 1 quart of water glass to 9 quarts of water that has been boiled and cooled. Place the mixture in a 5-gallon crock or jar, add about 14 dozen fresh clean eggs with sound shells, and store in a cool place. There should be at least 2 inches of the solution over the eggs. Such eggs have little commercial value, but they can be used satisfactorily in home baking. Eggs preserved in water glass are entirely wholesome but after several months sometimes develop a stale or strong flavor.

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[8] For specific instructions, see WARNER, K. F. COLD STORAGE LOCKERS FOR PRESERVING FARM-DRESSED MEAT. U. S. Bur. Anim. Indus. A. H. D. 16, 19 pp. 1935. (Rev. 1938 and 1939.) [Mimeographed.]

GRADING EGGS[9]

Purpose of Grading

The purpose of grading eggs is to classify or sort them according to their size, interior quality, and shell condition (fig. 11). Grading eggs also provides a basis on which payment may be made to producers. Selling his eggs "on grade" offers an incentive to the producer to give the best possible care to the eggs. Grading is accomplished largely through candling.

Grading also promotes a more satisfactory relation between buyer and seller. It provides a basis for mutual understanding of the quality of the eggs and helps to establish that confidence in the integrity of products that is so important to all commerce.

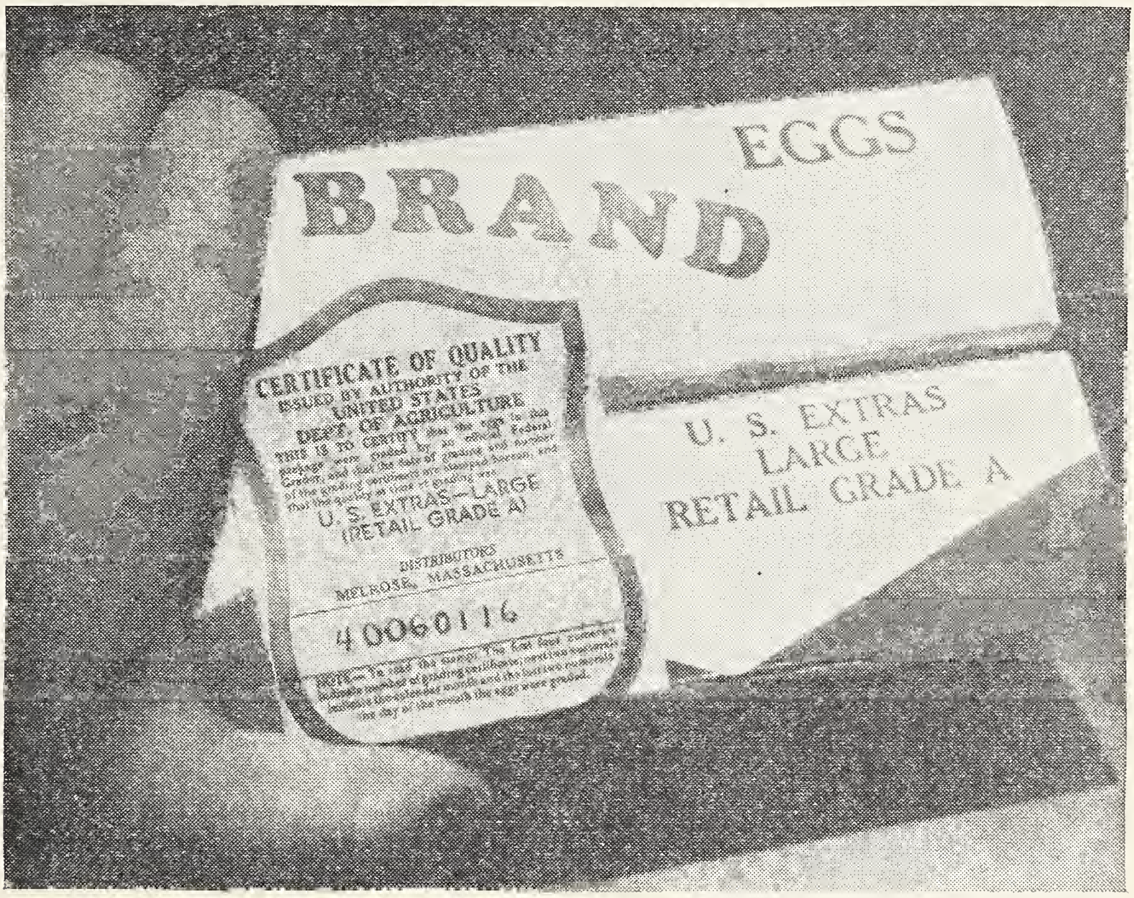

Figure 11.—Certificate of quality and grade.

Grading, particularly in the large markets of the country, also enables persons engaged in the egg trade to sort the eggs in accordance with the purposes for which they are best suited. The better eggs may be directed to the outlets demanding them, and those of lower qualities may be sorted out for use in the outlets which can use them to best advantage.

Owing to the consumer's difficulty in ascertaining the condition of eggs offered for sale, information regarding the size and general quality of eggs is distinctly helpful. A chance bad egg may weaken the consumer's desire for eggs; an egg slightly offgrade lessens his willingness to pay a good price. The expert candler knows practically to what extent eggs have changed from their state of original freshness. But the consumer must judge the fine distinctions of grade largely by what he reads on the label. Actual quality differences and adequate price differentials between grades in markets where they are well established give the purchaser a chance to choose with discrimination and to spend his money wisely.

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[9] By Rob R. Slocum, senior marketing specialist, Division of Dairy and Poultry Products, Agricultural Marketing Service.

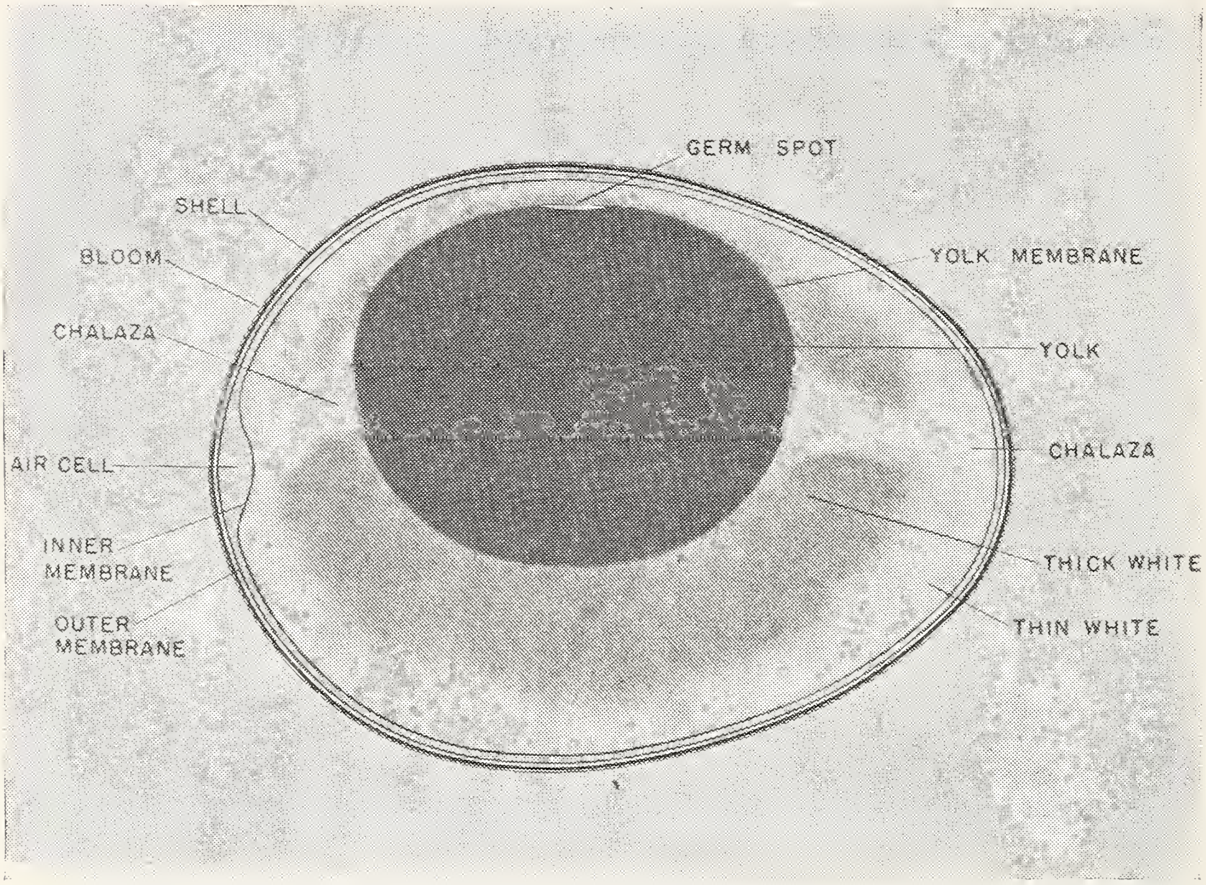

FIGURE 12.—Parts of an egg. (Diagram after sketch by C. W. Knox, Bureau of Animal Industry.)

Effective grading enables the trade to quote prices based on comparative values. The consumer's reaction to dependability of quality is likely to outweigh his hesitancy about buying the higher priced grades.

STRUCTURE OF EGGS

To understand what takes place in eggs when they deteriorate in quality and the factors that are considered in the pricing and utilization of eggs, it is desirable to have some knowledge of their structure and of the relationship of one part to another (fig. 12).

In a normal new-laid egg of good quality, the yolk is nearly spherical and of a uniform surface color. On the surface of the yolk, usually the upper side when the egg is broken out, there is a small area known as the germ spot. It is in this spot that embryo development in a fertile egg begins; consequently the size and appearance of the germ spot on the yolk, when viewed before the candle, is of importance in determining the grade. The yolk material is enclosed in a covering called the vitelline membrane, which holds the yolk in its normal shape. However, as an egg ages, the yolk tends to take up water from the white with a consequent enlargement in size, and the yolk membrane weakens as a result, permitting the yolk to assume a more flattened or spread-out shape.

The white, or albumen, of the egg consists of several parts or layers of thick and thin white. The yolk is suspended in the white by a twisted, ropelike mass at each end of the egg, known as the chalaza. The yolk floats and turns easily within the white.

Lining the shell are two membranes commonly described as the inner shell membrane, which is next to the contents of the egg, and the outer shell membrane, which is next to the shell. These membranes are close together and normally do not become separated except at the large end where, as the fresh egg cools and as it ages and water and gas escape from the egg, the two membranes draw apart and the space between them is filled with air.

The shell is the container for the liquid parts within. When new-laid, the egg is coated with a gelatinous covering which tends to seal the pores and gives the shell its bloom.

Perishability of Eggs

Unless eggs are handled and kept under good conditions, in a relatively short time they may reach a stage at which they are no longer edible. One of the first indications of deterioration is the evaporation of water from the white through the shell, with the consequent enlargement of the air cell. Another is the flattening of the yolk.

CONDITIONS INFLUENCING DETERIORATION

When fertile eggs are subjected to temperatures within the incubation range, which begins at as low as 68° F., the germ will begin to develop. This development will take place slowly or more rapidly, depending on how favorable the temperature conditions may be, and may result in a relatively short time in development of the embryo to the point at which blood veins are formed and the egg is no longer edible. Changes normally occurring in eggs proceed much more slowly at low temperatures (29° to 45°) than at a high temperature (above 70°). Consequently it is desirable to handle and transport eggs at low temperatures. Retailers and consumers also profit by holding eggs at proper temperatures (fig. 13).

Humidity also affects the rate of deterioration. Eggs should be held at a fairly high relative humidity; otherwise, water will evaporate more rapidly from them. However, too high humidity and stagnant air are likely to result in the development of mold on the eggs, quickly making them inedible.

Age has an important effect on egg quality, resulting in chemical as well as physical changes, which are discussed later. However, the extent of the effect of age depends greatly on conditions under which eggs have been held. Those only a few days old that have been held under adverse conditions may be inferior to those several months old that have been held under conditions favorable for their preservation.

Other factors, such as their proximity to materials that have a strong odor, also hasten the deterioration of eggs.

When deterioration proceeds to the extent that the eggs are no longer edible, they are classified as inedible. These include "black rots," "red rots," and moldy eggs. All of them represent a loss to producers as well as to handlers and dealers.

Determining the Quality of Eggs

One method of measuring the quality of opened eggs is the determination of the yolk index. This consists in measuring the height and diameter of the yolk after eggs have been broken out and the yolk separated from the albumen. The yolk index is the result obtained by dividing the height of the yolk by its diameter. Another method is to measure the percentages of thick and thin albumen. The higher the percentage of thick albumen, the better the eggs are considered to be. A third measure consists in comparing the opened eggs with a series of charts (prepared by Van Wagenen of Cornell), taking into consideration the height and the amount of the thick albumen and the appearance of the yolk. Candling attempts to accomplish this appraisal without breaking the shell.

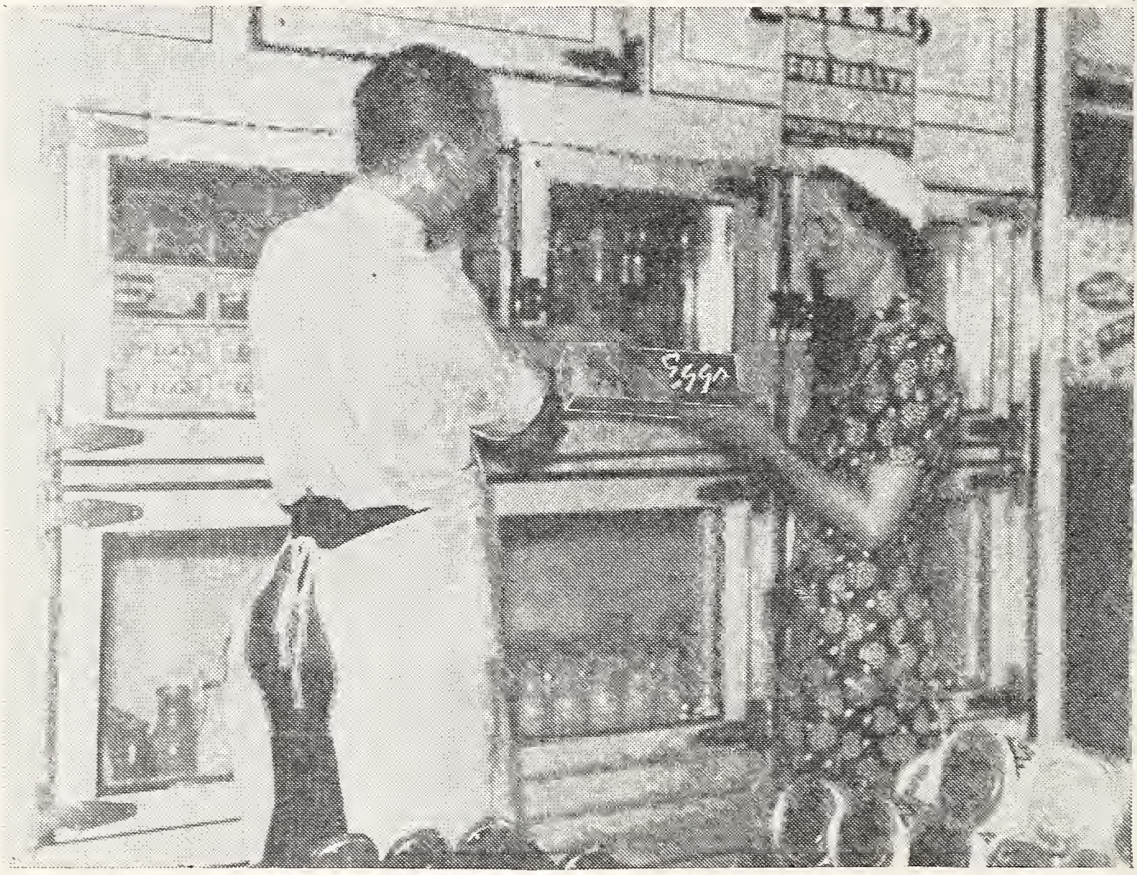

FIGURE 13.—Customer buying eggs out of a refrigerator. The progressive retailer plays a part in maintaining the quality of eggs.

Generally speaking, the aim in grading eggs by candling is to separate them into classes which indicate the quality one may expect when the eggs are subsequently broken and used.

PROCESS OF CANDLING

Candling consists in examining each egg separately in a darkened room by means of a device known as an egg candle that permits rays of light to pass through an egg, and as the egg is turned, to reveal its characteristics. Candling is by no means an exact science or art but is the best method available for determining the condition of eggs without breaking them, and its use is almost universal (fig. 14).

In commercial candling, two eggs are taken in each hand. One egg is held with the large end up and in an inclined position before the opening in the candling device. While held in this position, the egg is given a quick twist or turn on its long axis. This sets the yolk in motion and permits the appearance and behavior of the yolk to be noted. After one of the eggs in one hand is examined, an egg in the other hand is placed before the candle, and in the meantime the position of the two eggs held in the first hand is reversed. In this way, the eggs are alternated before the candle until all four have been examined and their quality determined.

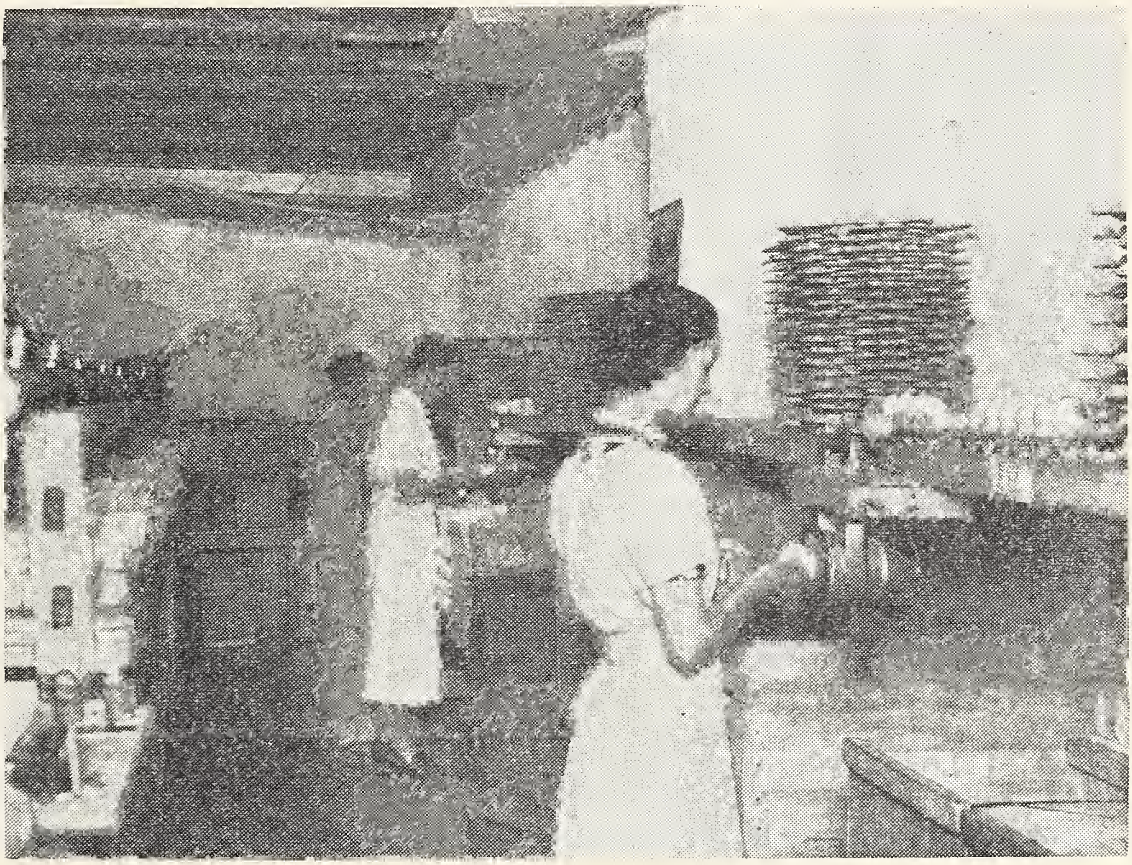

FIGURE 14.—Candling and grading eggs in a cooled and humidified room in a packing house.

In candling it is fairly easy to determine the eggs of high quality and those of very low quality, but it requires skill to differentiate those in the intermediate range. Persons who are skilled in this art, however, are able to grade eggs with reasonable accuracy.

Factors Considered in Candling and Grading

In candling eggs, the conditions of the shell, the air cell, the yolk, and the white are noted. Actually, of course, it would not be necessary to candle the egg in order to note the various differences commonly occurring in shell condition, except for "blind" checks or cracks.

SHELL CONDITION

In some cases, color and cleanliness of the shell are noted in daylight. In other instances, these characteristics are noted as a part of the handling operation in the darkroom during candling.

One of the first things observed is the degree of cleanliness. It is undesirable to pack eggs with soiled or stained shells along with clean-shelled eggs. The common practice is to remove eggs with badly soiled shells and to classify them as dirty eggs. These may also be subdivided according to the quality of their contents. Some eggs with only slightly stained or dirty shells are packed in the lower grades of clean-shelled eggs, but they should never be included in the top quality of clean-shelled grades.

In the better quality grades, only the normally shaped eggs are included. Eggs which have a serious deformity, abnormal or off-shape, are placed in the lower grades. The texture and character of the shell are also taken into consideration. Serious roughness or ridged conditions may mark eggs for a lower grade. If shells are very thin, the eggs are placed in a lower grade because of more rapid deterioration in thin-shelled eggs.

The shells of eggs are also observed to determine their soundness. Some eggs, however, may have only slight checks or cracks which are difficult to detect until the eggs are placed before the candle. Such eggs are often detected by the dull sound produced when they are clicked against a sound-shelled egg, or the cracks may be plainly visible. It is common practice to pack cracked eggs separately so that they may be directed to outlets where they can be used immediately.

SIZE AND POSITION OF THE AIR CELL

As the air cell enlarges and particularly as eggs are subjected to jars or shocks in handling and shipment, there is a tendency for the air cell to become "tremulous," that is, the shell membranes become separated over a larger area than that occupied by the air cell itself, and this permits a tremulous movement of the air cell as the position of the egg is shifted before the candle.

In some instances, the air cell may be "free" in the egg, permitting it to assume the uppermost position in the shell no matter how the egg is turned. This is due to the rupture of the inner shell membrane leaving the air free to move to a space over the contents of the egg.

POSITION AND MOBILITY OF THE YOLK

The yolk occupies the approximate center of a new-laid egg. If eggs are allowed to rest in one position, particularly if they are packed little end up, there is a tendency for the yolk to rise through the white and to approach the shell and shell membranes rather closely in the small end. This movement of the yolk out of its normal position results in the yolk's showing up much more prominently in candling and causes the quality of the egg to appear to be lower than it actually is.

When an egg is fresh and in good condition and particularly if it possesses a normally thick white, the yolk has a relatively slight movement away from the center when it is twirled before the candle. As an egg deteriorates in quality, the yolk tends to move more freely and to approach the shell more closely. It also becomes much more readily visible before the candle.

CONDITION OF YOLK AND WHITE

In addition to noting the position of the yolk in the egg and its degree of mobility, the operator also observes the yolk before the candle to see whether there are evidences of blemishes or damage spots on it. These appear before the candle as areas darker than the rest of the yolk. It is in this way also that the degree of germ development is noted. Very slight germ development will not be apparent before the candle, but as the germ increases in size, evidence of this growth can be seen, at first slightly and later as a distinct area.

A rather common defect found on the yolk of eggs is the presence of blood spots. The blood spots on the surface of the yolk occur in the formation of an egg and have no detrimental effect on its quality. However, their appearance definitely interferes with the salability of the eggs and, therefore such eggs are placed either in the inedible class or in the one of lowest edibility.

There is another type of blood condition, commonly known as a blood ring, which may be apparent on the yolk. This ring results when germ development has proceeded to the point at which blood lines have developed, and then, on the death of the developing embryo, this blood tends to gather in a ring about the germ spot. Eggs having this blood-ring condition are classed as inedible.

The character and condition of the white are determined, in candling, largely by the behavior of the yolk. If when the egg is twirled the yolk retains its position in the center, the white usually has a well-defined thick portion.

Occasionally foreign particles which are discernible before the candle as dark spots are seen in the white. The appearance of foreign matter in the white causes an egg to be graded down, as the whites of eggs of the higher grades should be clear and free from any foreign matter.

At times the whites have an unusual cast of color, which lowers the quality of the eggs. At certain seasons of the year, possibly because hens have had access to particular kinds of green vegetation, both the yolk and the white may have a greenish color. Such eggs are placed in the lowest grade of edible eggs.

UNITED STATES STANDARDS AND GRADES

The use of the United States standards as a basis for classifying eggs according to their quality or grade is becoming rather general in most parts of the country. At nearly all the larger terminal markets. Government-graded eggs may be purchased by the dealer or consumer. Eggs are packaged in cartons approved by the Agricultural Marketing Service, and the cartons are sealed with certificates of quality, also approved by the Service. The certificate states not only the grade of the eggs but also the size and the date of grading. Table 3 shows the detailed specifications for each United States grade:

TABLE 3.—*Conditions of shell, air cell, white, and yolk of eggs in United States grades*[1]

Item	Retail grade AA (U. S. Special)	Retail grade A (U. S. Extra)	Retail grade B (U. S. Standard)	Retail grade C (U. S. Trade)
Shell	Clean; sound; normal	Clean; sound; normal	Clean; sound; may be slightly abnormal.	Clean; sound; may be normal.
Air cell	One-eighth inch or less in depth; regular.	Two-eighths inch or less in depth; slightly tremulous.	Three-eighths inch or less in depth; may show movement not in excess of one-half inch.	May be more than three-eighths inch in depth; may show movement in excess of one-half inch; may be bubbly or free.
Yolk	Well centered; outline indistinct; motion sluggish; free from visible germ development and other defects or blemishes.	Fairly well centered; outline moderately defined; may be slightly mobile, free from visible germ development; practically free from other defects or blemishes.	Outline well defined; may be mobile; may show slightly visible germ development and other definite but not serious defects.	May be plainly visible; may be freely mobile and cast dark shadow; clearly visible germ development but no blood; may show other serious defects.
White	Firm; clear	Firm; clear	Reasonably firm; clear.	May be weak and watery.

[1] Eggs with dirty shells are graded U. S. Extra Dirty, U. S. Standard Dirty, U. S. Trade Dirty, according to their quality.

COLD STORAGE[10]

Nearly one-half of the total egg production of the United States occurs in March, April, May, and June. As eggs are a year-round food, some means must be employed for preserving them from the surplus-production season to the season of underproduction.

Various methods have been used, such as salting, brine pickling, and immersion in water glass or lime water, but no medium has been found that will keep shell eggs as satisfactorily from season to season as will cold air (fig. 15). Without any other preservative, a sufficiently low temperature will keep eggs in edible condition for nearly a year and in very good condition for 6 or 7 months, the usual length of time that eggs are held in storage. Because the heaviest production of eggs is in the spring, most eggs are stored in that season. The shortage in production usually begins about the middle of August, and the lightest production usually is reached in November and December. More eggs are stored in April and May than in any other months, and withdrawal from storage is greatest during the fall and early winter.

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[10] By Thomas W. Heitz, marketing specialist, Division of Dairy and Poultry Products, Agricultural Marketing Service.

Extent of Cold Storage

The use of cold storage as a means of preserving eggs began a rapid development about 1890. Until a few years ago, the stocks of cold-storage eggs increased regularly each year. During the last few years, however, owing to new practices of egg production, more fresh eggs than formerly have appeared in the fall and winter. In fact, year-round production is now becoming so general that it has a considerable effect on the extent of cold-storage holdings. The largest stock of shell eggs ever held in storage in the United States was that of 1930, when somewhat more than 11 million cases were stored. Cold-storage holdings of shell eggs during recent years have averaged approximately 7½ million cases.

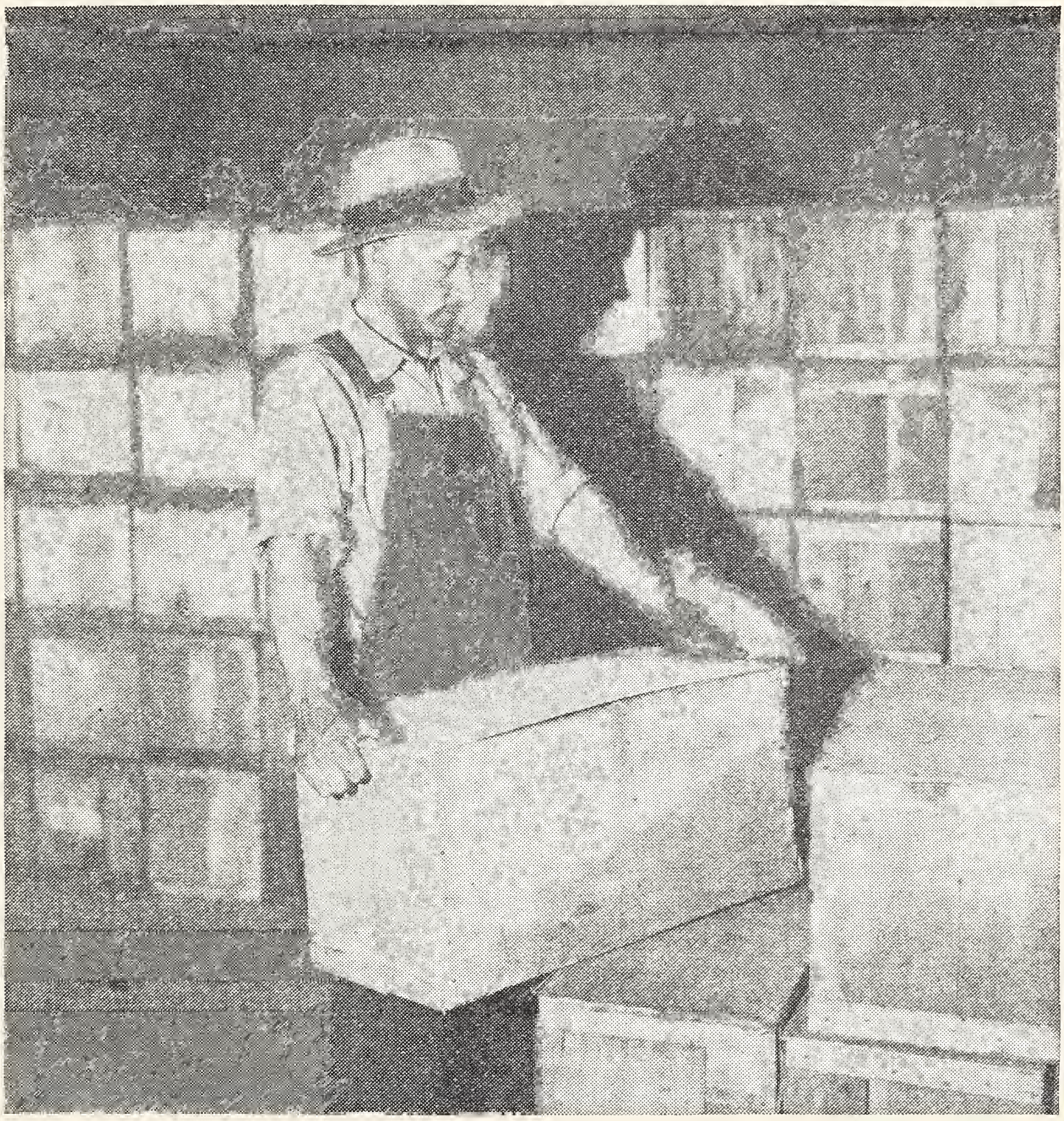
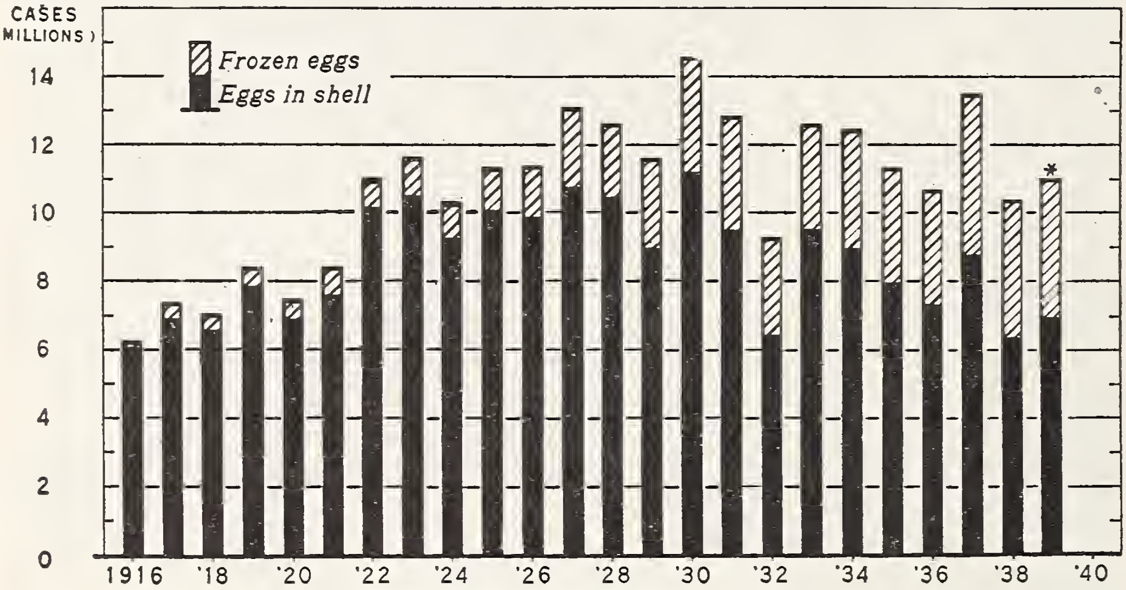


Figure 15.—Stacking candled and graded eggs in a cooled room greatly retards deterioration.

The economy in the use of frozen eggs, the lower cost for their storage as compared with that of shell eggs, and the elimination of spoilage during storage have been important factors in the commercial development of the frozen-egg industry. Many of the larger bakeries now contract for a year's supply of frozen eggs each spring. The largest stock on record was in 1937, when the peak holding on August 1 amounted to almost 167 million pounds, equivalent to about 4¾ million cases of shell eggs. The average peak holding for the 5-year period 1935–39 was approximately 136 million pounds. In recent years, the average quality of shell and frozen eggs stored (fig. 16) has been approximately 12 percent of the total estimated egg production of the country.

Location of Storage Warehouses

Warehouses for the cold storage of eggs are located in most sections of the United States. Many of them are country poultry- and egg-packing plants that have a capacity of 1 to 50 cars of eggs.



* ESTIMATED FROM STORAGE HOLDINGS OF JULY 1

FIGURE 16.—Cold-storage stocks of eggs in the United States on August 1, 1916–39.

The larger warehouses are in the big cities, principally at the main terminal markets (fig. 17). The warehouses at country packing plants are more or less available to the poultry- and egg-packing business, and eggs are usually stored at such plants for only a short period in the year. Many country packers begin storing eggs in the latter part of May, June, and July and continue until the price of fresh eggs begins to rise. After a short period in storage these eggs are shipped to market, where they are sold as short-held fresh stock, or they may remain in storage until fall or winter.

Storage warehouses at intermediate points in the larger cities in the Middle West are used to a considerable extent by country packers and city dealers. The advantage of storing eggs at such points arises through the use of the storage-in-transit privilege which is effective on most railroads and permits eggs stored at these interior points for several months to be shipped to any of the eastern markets on a through-freight rate from the point of origin.

The advantages of storage in warehouses located at terminal markets are that the eggs are here available for sale in the large centers of population and there is less risk that interference and delay arising from such causes as storms will create an egg shortage. Warehouses so located, by handling a variety of products, have also better opportunities of keeping their rooms filled.

Preparation for Storage

CLEANING STORAGE ROOMS

Most eggs have been withdrawn from storage by the first of January. By March the storage rooms usually have been renovated, the walls and ceilings sprayed or whitewashed, the rooms thoroughly aired and cleaned. The surest preventive of molds forming on eggs is a clean, sterilized egg room. If the room has been used for the storage of citrus fruits, apples, or other commodities that have a more or less decided odor, special care should be exercised in preparing the room for eggs. Ozone machines may be used to take odors out of the room. An ozone machine must be in good operating condition. It should be of a type approved by the Underwriters' Laboratories, and the installation and all connections should comply with the requirements of the National Electric Code.

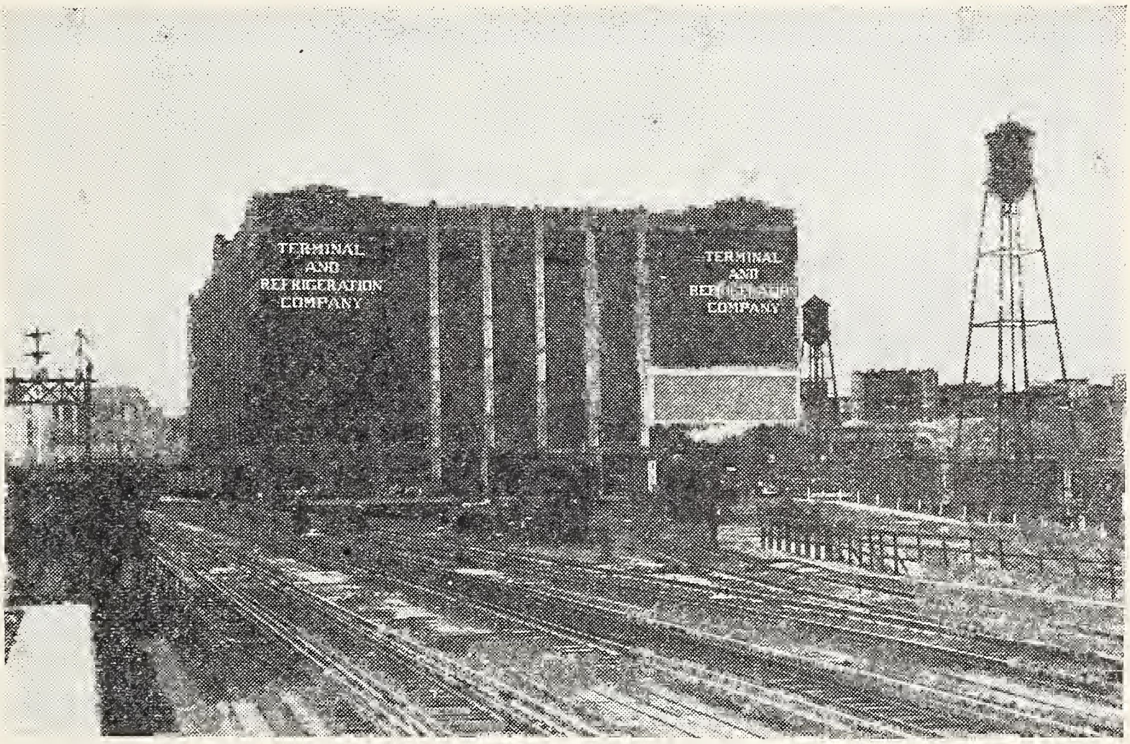

TERMINAL AND REFRIGERATION COMPANY
TERMINAL AND REFRIGERATION COMPANY

Figure 17.—Large quantities of eggs are placed in cold storage in warehouses at terminal markets.

REMOVING INFERIOR EGGS

Before being stored, all eggs should be carefully candled in order that "dirties," "cracks," "leakers," and eggs with sound shells but otherwise of low quality may be removed. Investigations have shown that in the storage of clean, new-laid eggs with sound shells and of high quality, only four to five eggs per case are lost through spoilage, even after 11 months of storage. The principal types of bad eggs found are "green whites," "crusted yolks," "moldy eggs," "mixed rots," "white rots," and "black rots." The first two types are characteristic of washed eggs that have been stored.

The likelihood of spoilage during the time that eggs are held in cold storage is markedly increased if the shells are dirty. In monthly withdrawals from September to March, inclusive, from a typical lot of dirty eggs stored in April, 22 to 59 bad eggs per case have been found by candling and breaking. The dirty eggs included those soiled with feces, mud, and blood, as well as stained eggs showing evidence of having been washed or of having come in contact with the wet, muddy feet of hens or with wet nests.

The commonest cause of deterioration of eggs with damaged shells is mold, which, in stocks stored in the spring, becomes pronounced in September and October and increases throughout the storage period. In cracked eggs stored in April and May, 44 bad eggs per case in September to 144 in March have been found. If the shells are dirty in addition to being cracked, the losses are much greater. Secondhand packing materials also hasten spoilage.

RELATION OF EGG QUALITY TO KEEPING ABILITY

The initial quality of eggs influences to a large extent their preservation by cold storage. Stale eggs with weakened membranes or with "hatch spots," which occur frequently in eggs marketed in the summer, lose their quality rapidly after a few months' holding in cold storage. The storing of stale and heated eggs during the summer months results in comparatively few bad eggs up to November, but from then until the end of the storage season, losses from spoilage usually amount to 1½ to 2 dozens per case. The most frequent types of bad eggs present in heated stock after storing are those with slightly stuck or broken-down yolks in various stages of spoiling (a form of mixed rot). However, the fact that many of the eggs marketed in the summer are shrunken and heated and do not keep well in storage does not necessarily indicate that they were not of good quality when put into storage. Eggs laid in July and delivered to storage within approximately 48 hours have been found to include a negligible number of bad eggs, even after a long period of storage.

In commercial practice comparatively few eggs are stored in the summer, and practically all that are stored during hot weather are withdrawn by November or December. Rather often in the summer, when the general supply of eggs is poor in quality, dealers withdraw from storage some of their spring stock to fill orders that require eggs of the better grades.

Spring eggs, commercially packed, uniformly have smaller numbers of bad eggs than those exposed to summer temperatures before being stored. Commercial Seconds usually have losses of 3 to 4 dozens per case during the ordinary storage period. Low-grade eggs, consisting of those which are dirty, small, shrunken, or heated, are seldom stored except for short intervals.

It may be convenient sometimes for the management of egg-breaking plants to buy large quantities of Seconds in the spring, store them for 1 to 2 months, and break and freeze them when the supply of eggs on the market is short and when otherwise the breaking room would be practically idle. There may be no appreciable increase in bad eggs during a few months' storage, but the general quality of the product is much lower because of increased staleness and higher bacterial content.

In stored spring and summer eggs, withdrawn at monthly intervals from November to March, most of the bad eggs that have developed are evident by November, as shown by candling and by breaking. Contamination may extend to eggs in adjoining pockets or through flats to the eggs beneath. An average of one to four sound-shell eggs per case has been found to be spoiled by leaking eggs. In spring Firsts a large proportion of the bad eggs with whole shells may be attributed to the presence of eggs which had been washed at some time previous to storage.

If dirt is left on the shells the eggs may be graded accordingly. They keep better in storage than washed eggs, unless the washing was done with the correct solution of lye water, discussed previously.

Shrinkage During Storage

There is an almost regular decrease in the net weight of eggs during the storage period. It amounts on an average to a net loss of 4 ounces per case per month in eggs stored for a 9-month period. The percentage of shrinkage may be greater than is generally credited by the produce trade, probably for the reason that in determining shrinkages most operators weigh the cases when they go into storage and again when they come out. When this procedure is followed, the gross and not the net weights are obtained, and this practice has led to the erroneous conclusion that there is little or no loss of net weight. The cases, flats, and fillers absorb some moisture from the air but mostly from the eggs during storage, with the result that the gross weight is but slightly affected. Dependable results will be obtained only by transferring the eggs to fillers and flats that have previously been weighed and deducting that weight from the gross weight after the eggs have been transferred.

Cases of eggs exposed to drafts from the outside, as through the opening of doors, will condense moisture from the incoming air, but under ordinary conditions the moisture from this source is small in quantity as compared with that from the eggs. Most of the moisture is taken up by the case and fillers during the first 4 or 5 months.

Physical and Chemical Changes

During the commercial holding of eggs in cold storage the air cell increases in size because of the evaporation of moisture; the white becomes thinner. After 6 or 7 months the white usually develops a yellow tinge, which deepens with the length of the storage period. The clouded appearance of the white is especially noticeable when eggs are separated in large quantities, as is done in a commercial egg-breaking room. The slightly yellow color does not destroy the beating quality of the white nor affect the porcelain-white color of the resulting froth. The yolk membrane weakens slowly; but if the eggs are fresh when stored, the whites and yolks can be separated, even after being stored for 11 months. However, the separation is usually not so easy as in the earlier part of the storage period. If the physical structure of the egg is weakened through its being stale or heated, or both, separation is difficult after it has been held in storage for only a few months.

Accompanying the evaporation of moisture from the egg is a transfer of moisture from the white to the yolk. There is also a gradual increase of ammoniacal nitrogen, at least during the earlier months of storage. As soon as the egg is laid, the hydrogen-ion value, by which the change in degree of alkalinity is measured, begins to increase. The increase in alkalinity, especially of the white, is very great.

It was found by Sharp and Powell that the introduction of carbon dioxide into the air of storage rooms is beneficial to eggs, greatly retarding deterioration.[11]

These workers estimate that if enough carbon dioxide were added to a storage room once each week for 6 months to give a concentration in the atmosphere of 1 percent, the cost of the carbon dioxide would be less than 1 cent per case of eggs. It would, however, be necessary to replenish the carbon dioxide often, unless the walls of the storage room were so treated as to make them more impermeable to carbon dioxide.

When carbon dioxide is used it must be kept in mind that continued exposure to concentrations of this gas as high as 400 parts per million of air is dangerous. Since equipment is not always available for testing the concentration, a gas mask should always be worn by anyone entering a room where this gas has been liberated. No person should be permitted to enter such a room alone or when no one else is around.

Sharp and Powell suggest oil dipping as a cheap and practical method that largely prevents the loss of moisture and decreases the rate of loss of carbon dioxide. If eggs are oil-dipped as soon as they are laid, the preserving effect of a low hydrogen-ion value is obtained, but the thick white becomes turbid during storage. If eggs which are not oil-dipped are maintained in an atmosphere containing sufficient carbon dioxide to keep the hydrogen-ion value near that of fresh egg white, a turbidity also appears in the white but disappears when the eggs are removed from the carbon dioxide atmosphere and some of the carbon dioxide is allowed to escape. Oil treatment of eggs is discussed in a later section.

MANAGEMENT AND COSTS OF STORAGE

STACKING OF CASES

Cases of eggs in the storage rooms should be piled in such a manner as to permit free circulation of air around each case. They should never be stacked to the top of the room and not higher than 10 inches below the lowest beam support of the ceiling. Quarter-inch or half-inch slats between the layers of cases permit cold air to circulate through each pile (fig. 18). Eggs should not be stored in rooms with other produce.

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[11] SHARP, PAUL F. THE PH OF THE WHITE AS AN IMPORTANT FACTOR INFLUENCING THE KEEPING QUALITY OF HENS' EGGS. Science 69: 278–280. 1929.

Stacking separate lots or grades of eggs by themselves makes withdrawal easy. Slatted racks at least 4 inches high should be placed on the floor so that the bottom of the egg case does not rest directly on the floor. Cases should never be turned during storage.

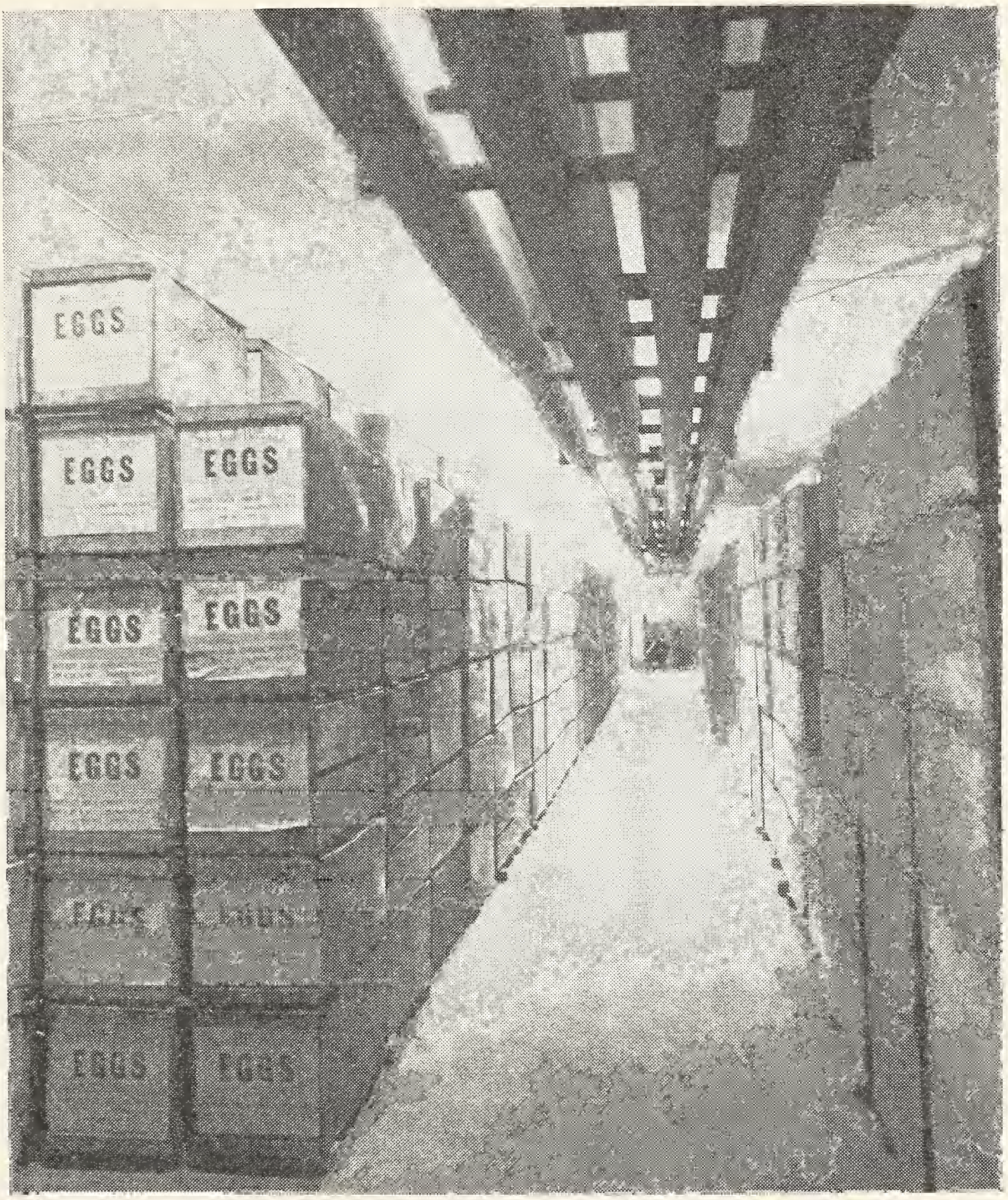

FIGURE 18.—Eggs in cold-storage warehouse. Stacked for proper circulation of air between cases.

VENTILATION, TEMPERATURE, AND HUMIDITY

Regardless of the degree of humidity maintained in the room, the air should be kept constantly in circulation to avoid air pockets. If the refrigerator coils are properly placed near the ceiling and the eggs are properly piled, a natural circulation of air will be maintained. If fans are used, the air should not be blown directly against the cases. When the indirect cooling system is used, fans that revolve at high speed blow the air over the cooling piles and then through the storage room, and little artificial ventilation is necessary.

Eggs should be stored at the lowest temperature at which they can be kept without causing the solidification of the interior, with consequent expansion of the contents and cracking of the shell. The freezing point of eggs is lower than that of water; consequently, eggs can be stored at temperatures lower than 32° F. The ideal temperature is 29°, with a variation of not more than 1° in either direction. Most modern cold-storage plants can hold the temperature within a variation of 3° by the use of thermostatic control. Regardless of the temperature in the storage room, it should be kept as nearly uniform as possible.

To prevent formation of mold, warehouses formerly kept rooms too dry for best preservation of eggs. To offset evaporation, in some warehouses, especially those in the Northwest and in semiarid sections or at higher altitudes, pans of water are placed in the rooms. A humidity held just below the point at which mold is likely to grow is desirable. Most warehouses attempt to hold the relative humidity between 90 and 92 percent, and at a higher percentage early in the storage season than later. Some artificial means of providing constant air circulation is necessary where high humidity is maintained.

STORAGE CHARGES

Warehouses generally charge double the regular egg-storage rate for the first month, in order to take care of such expenses as those for unloading cars and paying for clerical help. A few, however, charge the regular rate for each month's storage and then make an additional charge for handling. This latter charge is usually based on time and varies according to local labor conditions and the number of eggs handled.

Storage units are usually figured in carlots, consisting of 400 cases. Most warehouses give a reduction in rates to those who store more than 10 carlots for the season. Most of the warehouses in 1939 charged for less than carload lots, 16 cents per case for the first month and 8 cents for each additional month, with a season rate (usually terminating January 1) of 60 cents per case. In carlots, the average charge is about one-half cent per dozen, or 15 cents per case, for the first month and 7 to 7½ cents per case for each additional month, with the season rate of 50 to 55 cents per case.

These charges usually include insurance to cover fire, lightning, wind, and sprinkler leakage, but some warehouses charge insurance in addition to the storage rate, usually 12½ to 15 cents per $100 a year. On request of the holder, some storage companies insure the holdings by the month, charging slightly more than the yearly rate.

UTILIZATION OF EGGS AFTER STORAGE

For all practical purposes cold-storage eggs can be used in the same manner as fresh eggs, although their flavor is usually not so desirable as that of fresh eggs. The cold-storage taste develops usually after about 3 or 4 months of storage and gradually becomes more intense as the storage season progresses. It is especially noticeable when the eggs are soft-boiled or poached. The flavor is not so marked in the white as in the yolk, which contains a large percentage of fat. For general cooking purposes, however, and in nutritive value, there is little difference between the storage egg and the fresh egg.

On withdrawal from storage, eggs should be carefully candled before they go to the retailer even though they were carefully candled previous to storage. One bad egg may do more harm than the saving in the cost of recandling would justify. Storage eggs should be marketed as rapidly as business practice will permit, kept as cool as possible, and used promptly.

NUTRITIVE VALUE OF EGGS AND THEIR UTILIZATION IN HOME COOKING[12]

Eggs are important as human food because of their nutritive value and their usefulness in combining with other foods. They merit care in buying.

The homemaker can tell little about the quality from an examination of the exterior of eggs. However, a dull-appearing shell is an indication of better quality than a glossy, smooth shell. In purchasing eggs, the buyer will do well to patronize a market where the retailer keeps the eggs in a refrigerator. Size is to be considered —how much egg one is getting for the price paid. Shape and uniformity may be noted, and cleanness is important, but the color of the shell makes no difference. It is well to use only the best grades for frying, poaching, or cooking in the shell. Less expensive grades serve well for other cooking purposes. The consumer can usually buy both new-laid and storage eggs graded under standards set up by the United States Department of Agriculture or by State authorities. If the eggs have been properly handled, either standard is satisfactory. Ten States now make grading compulsory. Department of Agriculture grading is done only at the request of shippers and marketing agencies. The four Government grades are as follows: U. S. Special, or Grade AA; U. S. Extra, or Grade A; U. S. Standard, or Grade B; and U. S. Trade, or Grade C. Specifications of condition for each grade are given in table 4. The three upper grades, under certificate or seal, are also marked as to size: "Large" eggs, weight 24 ounces to the dozen; "Medium" eggs, not less than 20 ounces; "Small" eggs, 17 ounces to the dozen.

It is advisable for the consumer to get the eggs from the store refrigerator to the kitchen refrigerator as soon as possible. A week's supply is a sufficient quantity to obtain at one time (fig. 19). When an egg is broken out of the shell, the yolk should be upstanding, and the white should have a good proportion of thick, gelatinous albumen. A good egg has no off odors or flavors.

Average consumption of eggs by families in the United States appears to be about a dozen and a half a week. This figure takes account of rich and poor and of large and small families in all parts of the country. Nonrelief white families on farms in the Northeast averaged 31 eggs a week, whereas comparable small-city families in the same section used only 20, according to a study during the summer and fall of 1936. In the Southeast, white families in the small cities studied bought an average of 22 eggs, but Negro families living there bought only 7 a week.

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[12] By Florance B. King, home economics specialist, and Rowena Schmidt Carpenter, home economics specialist, Foods and Nutrition Division, Bureau of Home Economics, and other members of the Bureau staff.

Family income, together with the number of persons it must support, affects egg consumption. In villages of the North and West, 2-person families (husband and wife) with incomes between $500 and $1,000 consumed an average of 8 eggs a person a week. Families of husband, wife, and 1 or 2 children less than 16 years of age at the same income level used 5 eggs a person a week; families of the same size with incomes of $3,000 to $5,000 consumed about 7 eggs a person a week.

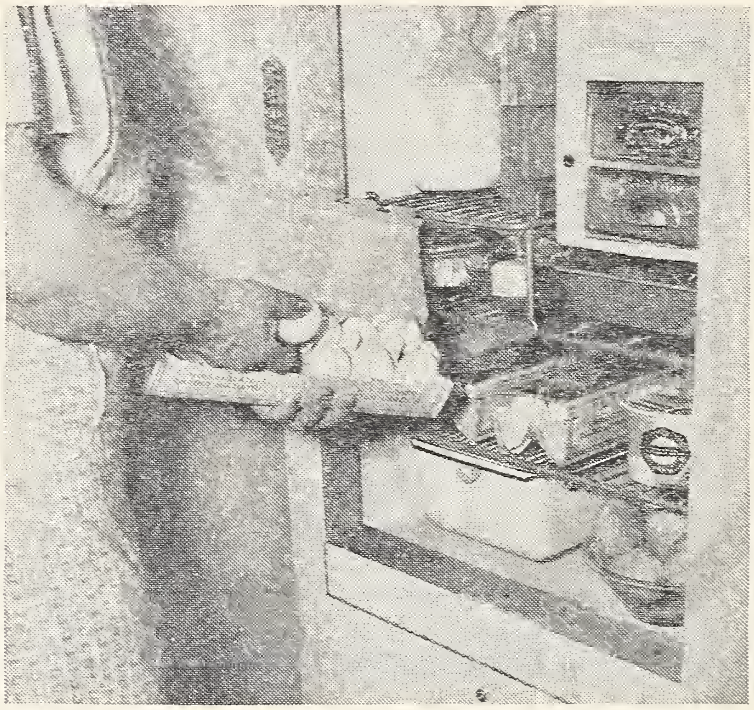

FIGURE 19.—The week's supply of eggs. Eggs retain their freshness longer if kept cold and away from foods that impart odors to them.

NUTRITIVE VALUES

In its combination of nourishing qualities, flavor, and color, and in its utility in cooking, the egg is unique. Only its more important constituents and their value in the diet are discussed here.

PROTEINS, FATS, AND MINERALS

The egg is a good source of efficient protein, that is, protein of high biological value. The white averages about 11 percent of protein, which is mainly albumin. The rest of the white is chiefly water. The yolk contains an average of about 16 percent of protein and about 32 percent of fat and lipoids. The iron content of the yolk is high compared with that of most other foods, and experiments indicate that all this iron is present in a form available to the body. Although the quantity of iron in the white is low, the yolk is rich enough to make the whole egg rank as an excellent source of this important element. Eggs are also a source of calcium and are rich in phosphorus. The edible part of the egg yields about 715 calories per pound, which corresponds to about 635 calories per pound as purchased, since the weight of the shells is included.

VITAMINS

Eggs are an important source of several of the vitamins that are necessary for good nutrition. The yolk contains vitamins A, B_1 (thiamin), D, E, G (riboflavin), nicotinic acid (the pellagra-preventing factor), and small quantities of vitamin K (the antihemorrhagic factor). In the white, riboflavin is the only one of the recognized vitamins that has been found in appreciable quantities.

Although for all practical purposes an average market egg may be considered a good source of vitamin A, the actual vitamin A content of eggs varies widely, depending chiefly on the quantity of this vitamin in the diet of hens. Vitamin A values were determined recently in the Bureau of Home Economics on a representative sample of fresh eggs, both graded and ungraded, purchased from dairies, grocery stores, markets, and direct from the farm. The results of these studies indicate that an average winter market egg provides only about 340 International Units of vitamin A (about 1,880 International Units per 100 grams of yolk, or 700 International Units per 100 grams of whole egg), whereas the average summer market egg provides about 670 International Units (about 3,760 International Units per 100 grams of yolk or about 1,400 International Units per 100 grams of whole egg).

If the ration of a hen is rich in vitamin A, sharp decreases in her vitamin A intake do not at once produce correspondingly sharp decreases in the vitamin A content of the eggs she lays. However, if a hen is kept on a diet low in vitamin A for a considerable time, her body tissues are gradually depleted and the eggs produced have a gradually diminishing content of vitamin A; eventually, egg laying will decline or cease altogether.

Though many food products having a yellow or orange color are rich in vitamin A, the intensity of the color of egg yolk is not a reliable indication of its vitamin A value. Eggs from hens having a diet abundant in green leafy feed will have highly pigmented yolks containing a high concentration of provitamin A (vitamin A inactive carotenoids which can be converted into vitamin A itself in the animal body). Yellow corn in the diet increases the depth of color of the yolk but provides less provitamin A than green leafy feed. Eggs from hens on a diet low in pigments but containing considerable cod-liver oil or other fish-liver oil will have light-colored yolks rich in vitamin A, as fish-liver oils provide vitamin A itself (a very pale yellow compound) abundantly. Therefore, either pale or deeply colored yolks may or may not be high in vitamin A.

Eggs vary somewhat in thiamin (vitamin B_1) content, according to the amount of this vitamin in the diet of hens. An average-sized egg provides about 60 micrograms (20 International Units) of vitamin B_1; 100 grams of whole egg provide about 139 micrograms (43 International Units) of this vitamin, while 100 grams of egg yolk provide about 360 micrograms (120 International Units). There is no appreciable amount of vitamin B_1 in the white.

Only small amounts of vitamin D are generally contributed by eggs, but by suitable feeding practices it is possible to produce eggs having a high vitamin D content.

The riboflavin (vitamin G) content of eggs may also be influenced to some extent by the amount of this vitamin in the diet of hens. An average-sized egg provides about 230 micrograms of riboflavin. The yolk is approximately one and one-half times as rich in this vitamin as the white. One hundred grams of yolk provide about 600 micrograms of riboflavin, whereas 100 grams of white provide about 400 micrograms of this vitamin. Further references to vitamins occurring in eggs appear in the sections Eggs in the Daily Diet, and Influence of Feeds.

FIGURE 20.—A satisfying breakfast. Eggs combine well with other foods both in nutritive value and in attractiveness.

EGGS IN THE DAILY DIET

Eggs in some form may well appear in the family diet every day (fig. 20). Their excellent contributions to nutritive needs make them especially important for children during all the years of growth. Even the baby receives his daily quota of egg yolk as an early supplement to his milk diet. Because of their building properties, eggs are valuable during convalescence and in many types of illness.

The proteins in eggs, like those in meat and milk, are called efficient because they are well utilized by the body. Efficient proteins are needed in every living cell; they are used in building the soft tissues of the body (fig. 21, *A*). The egg yolk is a source of iron that is necessary for the formation of red blood cells and prevents a type of nutritional anemia.

An egg or two a day will make considerable contribution to the daily requirement for vitamin A, thiamin, and riboflavin, and at the same time furnish some of the pellagra-preventing factor and vitamin D. It is because of their mineral and vitamin content that eggs are listed among the protective foods (fig. 21, *B*).

ALLERGIC SENSITIVENESS TO EGGS

The terms "food allergy" and "food idiosyncrasy" are used to describe unusual reactions of the human system to foods. Symptoms of food allergy are varied. Acute digestive discomfort, attacks of hives or certain types of eczema, or disturbances of the respiratory system are some of the symptoms that may signify allergic sensitiveness.

Any wholesome food may cause allergic reactions in an individual. Although most persons can digest eggs satisfactorily, some are allergic to them. It is therefore wise for everyone to know something of the cause and treatment of egg allergy.

This condition usually results from eating eggs either alone or combined with other foods. However, the disturbance may be caused also by some external contact with raw or dried egg white, such as handling freshly broken egg shells or dried egg white in baked products. Allergic symptoms may result from eating exceedingly small quantities of egg; they are also caused by an unduly large intake of egg at one time. Raw-egg proteins are more frequent offenders than are the proteins of cooked or dried egg. The difficulty is due to egg proteins passing into the blood stream in their original complex state.

Sensitiveness to eggs may occur at any age. However, it is most frequent during infancy; hence the warning by pediatricians and nutritionists that egg yolk only should be given at first and that it should be introduced into the baby's diet in small quantities and the portion gradually increased. The first time that egg yolk is given, at about the age of 3 months or earlier, the quantity should consist of one-fourth of a teaspoon or less of hard-cooked yolk. If this causes no disturbance, it should be increased very gradually. By the end of the first year the baby usually receives a whole egg daily. If, on the other hand, the infant does not digest eggs normally and symptoms of egg sensitiveness appear, the advice of a physician should be obtained immediately. He may recommend omitting egg for a time and then introducing it again by adding to the milk formula or the cereal only as much cooked yolk as will cling to the tines of a fork.

Occasionally an allergic condition of this kind persists into adult life, but in many cases it gradually diminishes or disappears entirely. The importance of avoiding or overcoming egg allergy can scarcely be overemphasized in view of the valuable contributions that eggs make to nutritive needs. Medical advice should be sought immediately if symptoms of allergy appear.

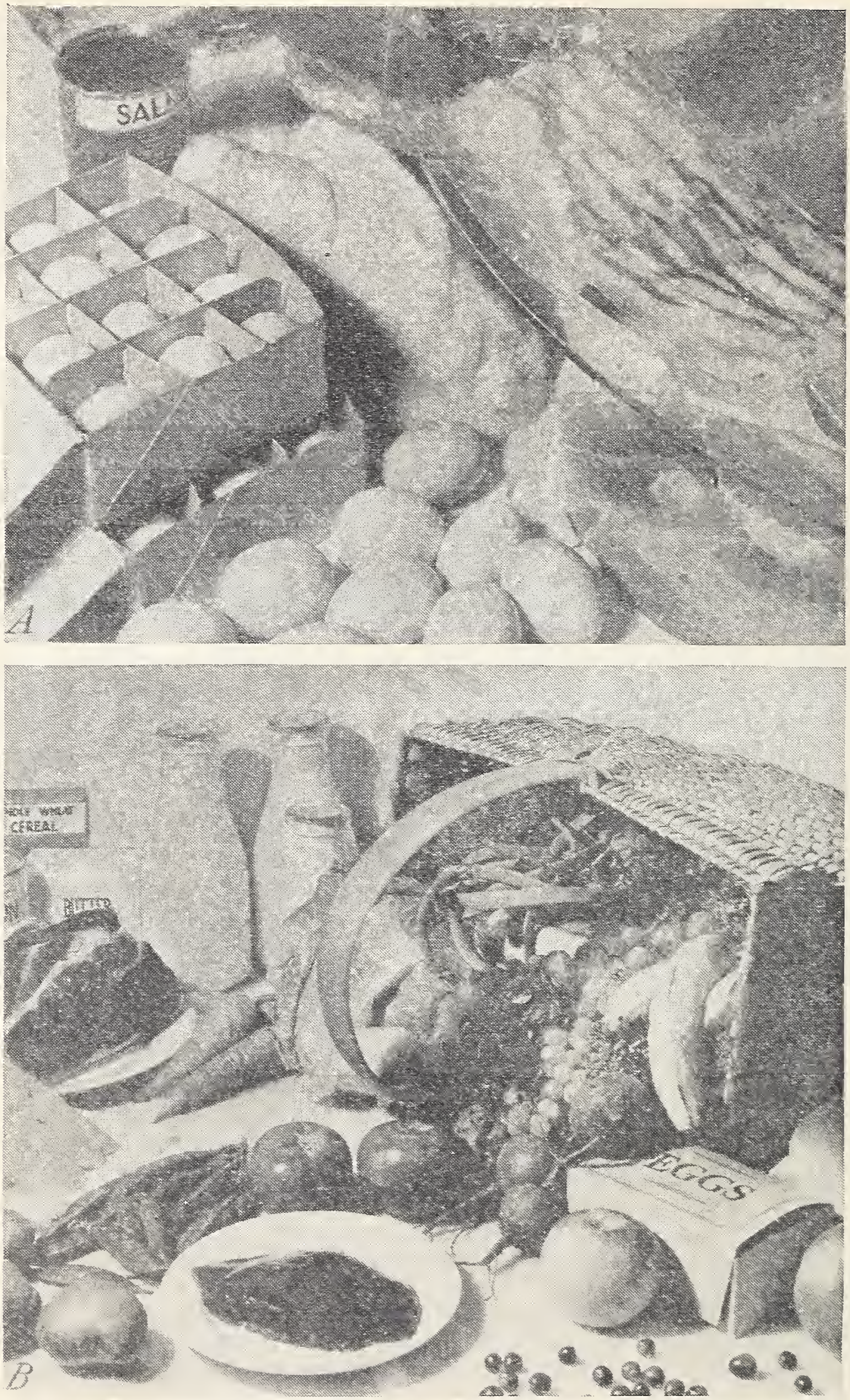

FIGURE 21.—Eggs rank among the leading foods. *A*, Like fish and meat, eggs are good protein foods. *B*, Eggs and other protective foods are important in the well-balanced diet.

KINDS OF PROTEIN AND CONDITIONS AFFECTING COAGULATION

Egg white is essentially a solution of proteins, although it has traces of other substances. It contains at least five proteins, the most important being albumin, which composes about 70 percent of the total protein. Of the other proteins, mucin is found mainly in the firm egg white, which fact may partially account for the differences in the physical properties of the firm and fluid whites. The main protein of the egg yolk is ovovitellin, which is dispersed around the fat globules to form an emulsion.

Although albumin is soluble in water, the other proteins of egg white and the ovovitellin of the yolk are not. However, eggs may be used to make nutritious beverages, such as egg-and-milk shake, or eggnog, since a mixture is formed that does not separate.

The proteins of both the white and the yolk are coagulated by heat. Several factors affect the temperature at which coagulation takes place, but in any case the temperature of coagulation is below 194° F. (90° C.). If heated slowly, egg white begins to thicken at 140° F. (60° C.) and sets to a jelly at 147° F. (64° C.) or 149° F. (65° C.). The yolk begins to thicken at 149° F. (65° C.) and will not flow at 158° F. (70° C.). The combined white and yolk begins to thicken at 149° F. (65° C.) and sets to a jelly at 158° F. (70° C.) to 167° F. (75° C.). Some of the factors affecting the temperature of coagulation are as follows: Length of time and temperature of heating, concentration of protein, reaction of the solution or mixture, and the presence of certain substances such as sugar or salts.

The rate of coagulation increases with temperature, that is, an egg cooks more rapidly when at boiling than at simmering temperature, but the consistency is different. The more protein present the lower is the temperature of coagulation. The addition of sugar to egg mixtures increases the temperature at which they set. Acid and salt decrease the temperature of coagulation.

When egg white is heated, the coagulated protein holds within its meshwork the solution of other constituents and forms a jelly. If heating is continued the proteins begin to shrink until they no longer can hold all the solution, and the jelly begins to exude liquid. The protein in the shrunken state is tough and slightly rubbery. The egg yolk, because of the intimately mixed fat, first becomes waxy when heated, and then mealy rather than tough. Control of temperature is important in cooking eggs.

Methods of Cooking

COOKING IN THE SHELL

When eggs are cooked in the shell, the product may be soft cooked or hard cooked, depending on the time that the eggs are maintained at the temperature of coagulation. To produce a uniform texture and to prevent shrinkage and toughening of the white next to the shell while the center is heating, the cooking temperature should be only slightly above the coagulation point. This may be accomplished by dropping the eggs in cold water and bringing to a simmering temperature of 185° F. (85° C.), or by dropping the eggs in boiling water and then setting the pan over hot water or over very low heat. The cold eggs will immediately reduce the temperature of the water below the boiling point. By this last method, the relation of the time that the eggs are left in the hot water and their consistency will depend on the number and temperature of the eggs when placed in the water and the quantity of water used. Once the method is standardized (for instance, four eggs just removed from the refrigerator and dropped into a quart of boiling water) the time of cooking becomes a measure of consistency of the egg. It requires about 30 minutes to cook eggs hard at simmering temperature.

Besides shrinking and toughening the egg white, cooking at high temperature for a long time causes the formation of hydrogen sulfide. This gas comes into contact with the iron in the yolk of the egg and forms ferrous sulfide, which causes a green discoloration on the surface of the yolk. If the eggs are cooled quickly in cold water immediately after cooking, the hydrogen sulfide will diffuse to the outer surface and less discoloration will take place.

Another difficulty which often occurs when eggs are cooked in the shell is the adhesion of the shell membrane to the hard-cooked white when the eggs are peeled. Although there seems to be no way to prevent the sticking of the shell, if the eggs have that tendency, cooking at a simmering temperature and cooling immediately in cold water seem to reduce the sticking.

POACHING

The procedure for poaching eggs, as far as temperature is concerned, is the same as for eggs cooked in the shell. Since heat penetration through the shell is rather slow, poached eggs can be cooked for a shorter time to obtain the same consistency. If the eggs have a considerable portion of liquid white, loss of the white through scattering may be reduced by dropping the eggs in boiling water and then lowering the temperature to simmering. The addition of three-fourths of a teaspoon of salt to each pint of water used in cooking will produce more rapid coagulation. Cooking the egg in a ring is an even better method to prevent scattering.

The best eggs for poaching are those with a firm white and a rounded yolk. Since eggs flatten on standing out of the shell, they should be broken just before cooking.

FRYING

The temperature of the fat used in frying eggs can be kept low, just as when cooking in water. If it is too high the white becomes dehydrated and crisp in texture. Although some browning of the egg is desirable for flavor, if the egg is to be cooked hard a low temperature must be maintained to coagulate the entire egg without the outside becoming too tough. Coagulation can be speeded by spooning the fat over the top of the egg while cooking.

OTHER METHODS

Another popular method of cooking eggs is to scramble them. Some cooks prefer to beat them first, and in the preparation of scrambled eggs, milk, minced or shredded meat, or other foods may be added to give greater bulk or a modified flavor. They are cooked over very low heat or in a double boiler. Still another popular egg dish is the omelet, which likewise is prepared in various ways and is often cooked in a divided pan to facilitate easy turning. The principles of coagulation and cooking for these dishes are essentially the same as outlined for cooking in the shell, poaching, and frying.

Uses in Food Combinations

Besides contributing color and flavor to food, eggs are valuable in combining ingredients of foods. This value lies chiefly in the protein, which is present in colloidal form. The proteins coagulate on heating, thereby thickening liquids with which they have been mixed, as in custards; leavening or providing lifting power, as in cakes; binding ingredients, as in croquettes; helping to form an elastic framework, as in popovers; or enmeshing suspended material, as in cloudy coffee and soups, making them clear on straining.

THICKENING WITH EGGS

Because coagulated proteins are able to hold liquid in a jelly state, eggs can be used as thickening. The character of the jelly will depend on the proportion of liquid to eggs and to the treatment during coagulation. There is a limit to the quantity of liquid which the jelly will hold; therefore a definite quantity of egg is used with a certain quantity of liquid to obtain an optimum jelly. If the mixture is undisturbed during coagulation, as in baked custard, the jelly sets in one piece, but if it is stirred a viscous fluid is formed. Stirred custards curdle more easily than baked ones, because of the increased coagulation due to stirring. The coagulation temperature of an egg-milk mixture is higher than that of egg alone. It depends on the proportion of ingredients, such as the quantity of egg and sugar, and on the rate of heating. The more sugar that is present, the higher is the coagulation temperature. An increase in the quantity of egg or a slow rate of heating lowers the temperature at which a custard sets.

However, just as with egg alone, the mixture of eggs and liquid must be cooked at a moderate temperature and only long enough to form a jelly. Otherwise the proteins shrink and the mixture becomes watery. This point is illustrated in scrambled eggs, which become firmer as they are cooked but which become watery if cooked too quickly or too long. Baked custards separate and stirred custards curdle for the same reason.

If a high temperature is used in baking egg mixtures, the outer part becomes tough before the inside has set. If the temperature used is just above that of coagulation, the outer portions will be tender when the center is sufficiently done. Therefore, custards and other egg dishes are set in a pan of hot water and cooked in a moderate oven to maintain a uniformly low temperature, or are cooked over hot but not boiling water. They should be removed from the heat as soon as coagulation takes place so that separation of liquid will not occur.

When egg is used in combination with starch as a thickening agent, it is necessary to cook the starch with the liquid before the egg is added, since each thickening agent requires a different temperature and time of cooking. This is illustrated in making pie fillings and salad dressings which contain both eggs and starch. However. it is important that the mixture be heated above the coagulation temperature of the egg, after it is added, or the mixture may become runny on standing. In pie fillings the temperature is generally higher than in custards, as more sugar is used.

On the other hand, in salad dressings and lemon fillings, which contain acid, the temperature of coagulation is lower than in custards. If the mixture is heated at too high a temperature, there is a continued action of the acid on the protein, and the mixture may lose its thickened consistency and become runny.

LEAVENING WITH EGGS

When egg white is beaten, a foam is formed which consists of many tiny air bubbles surrounded by a film of coagulated protein. The air thus incorporated provides lifting power in sponge-type cakes and souffles, or helps to prevent the formation of large crystals in frozen desserts or in candy. The change produced by beating is due to the low surface tension of the white and the stability of its surface films. The coagulation of the protein, which gives rigidity to the foam structure, is in part the result of the mechanical agitation of beating.

The yolk when beaten does not increase in volume as much as the white, and the foam is much finer. If the white and yolk are beaten together, the foam has more of the characteristics of the beaten yolk. Apparently the presence of the emulsified fat in the yolk decreases the foaming power of the proteins of the white.

The addition of certain substances to egg white and other factors affect the volume and stability of the foam. Salt, sugar, and acid in certain concentrations increase its stability. Acid also increases the volume by making the proteins more elastic and, therefore, able to enclose more air bubbles. The temperature of the egg white affects the speed with which the foam is formed and the volume obtained. Since the surface tension of egg white is lower with increased temperature, eggs at room temperature will beat more readily than those taken directly from the refrigerator.

The whipping quality of egg white seems to vary with its viscosity or the quality of fluid white that it contains. This in turn is affected by individual characteristics of the hen, season in which the egg is laid, the age of the egg, and perhaps other factors. The more viscous the egg white, the longer it takes to form a foam. Furthermore, the quantity of foam is less, but the stability is greater. This last factor is important, as the foam must be sturdy so that when the other ingredients are added the foam structure will be able to support these heavier ingredients (fig. 22).

The type of beater affects the volume of the egg foam and the size of the air bubbles or cells. A flat egg beater used on a flat plate gives large air bubbles and volume. If the wires of the egg beater are too coarse, coagulation may take place too rapidly and the foam will be less stable. A rotary beater makes a finer foam of slightly less volume than a flat beater. However, the energy and time required to produce the foam are less.

The stages of foam formation and further beating and the uses at each stage are as follows:

Foaming.—Large air bubbles; transparent; flows easily. Used for clarifying, coating, thickening, and emulsifying.

Soft foam.—Air bubbles smaller; white, glossy, moist; flows; does not follow into peaks when egg beater is removed. Used for soft meringues or angel-food cakes made by the meringue method.

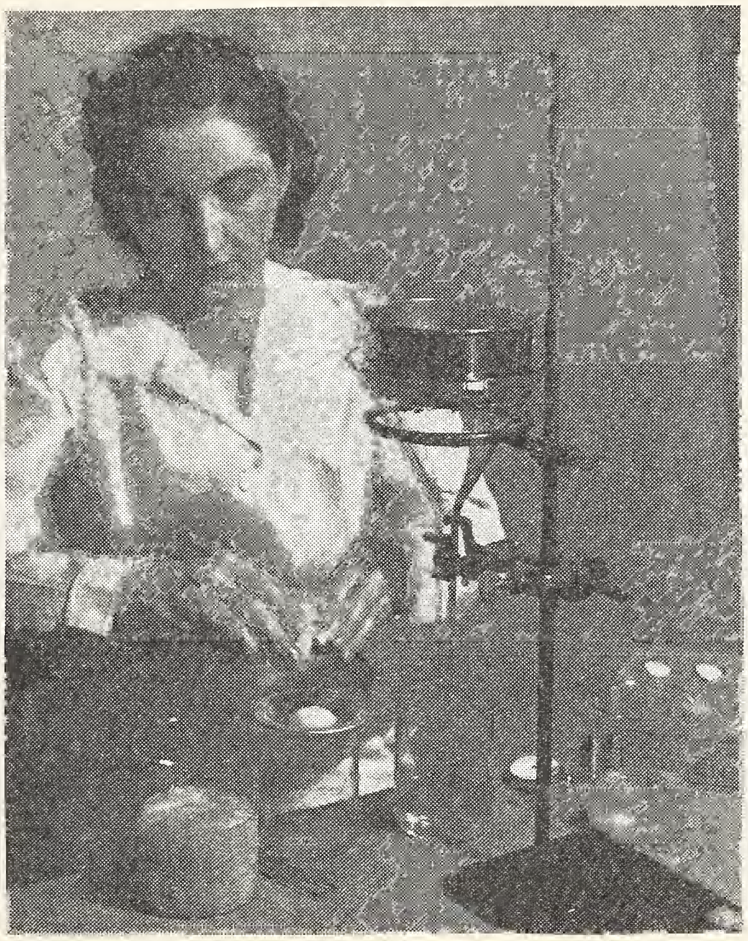

FIGURE 22.—Separating egg whites into the firm and liquid portions to test their comparative foaming quality.

Stiff foam.—Only slightly foamy, air bubbles smaller; glossy, moist; flows slightly; forms into soft rounded peaks when egg beater is removed. Used for sponge-type cakes.

Stiff.—No longer foamy, air bubbles smaller; glossy, smooth, moist; may slip in bowl if tilted; peaks pronounced and pointed and do not fall over; can be cut. Used for omelets, souffles, cakes, frostings, candies, hard meringues.

Dry.—White but dull; small flakes beginning to show; very rigid and somewhat brittle. Particles will be thrown off from the beater. Overbeaten for leavening purposes.

HANDLING THE FOAMS

When salts or acids in the form of cream of tartar or lemon juice are used to stabilize the foam for sponge-type cakes, they are added at the foaming stage to bring about the best effect. Sugar is best added at this stage, but it prolongs the time and energy required for beating. Therefore, unless a power beater is used, it is added after the foam is formed. The use of part of the sugar to increase the strength of the foam for sponge-type cakes decreases the amount of air lost in mixing. The remainder of the sugar, which is sifted with the flour, separates the flour particles, making it easier to fold into the meringue. Since the air beaten into the egg white is the leavening, the foam should be used immediately after beating before the air has an opportunity to escape. If the foam is covered with the mixture to be combined, the air escaping through mixing will go into the mixture rather than be lost. A gentle folding motion is used in combining so that the delicate air cells will not be broken as they would with stirring or beating.

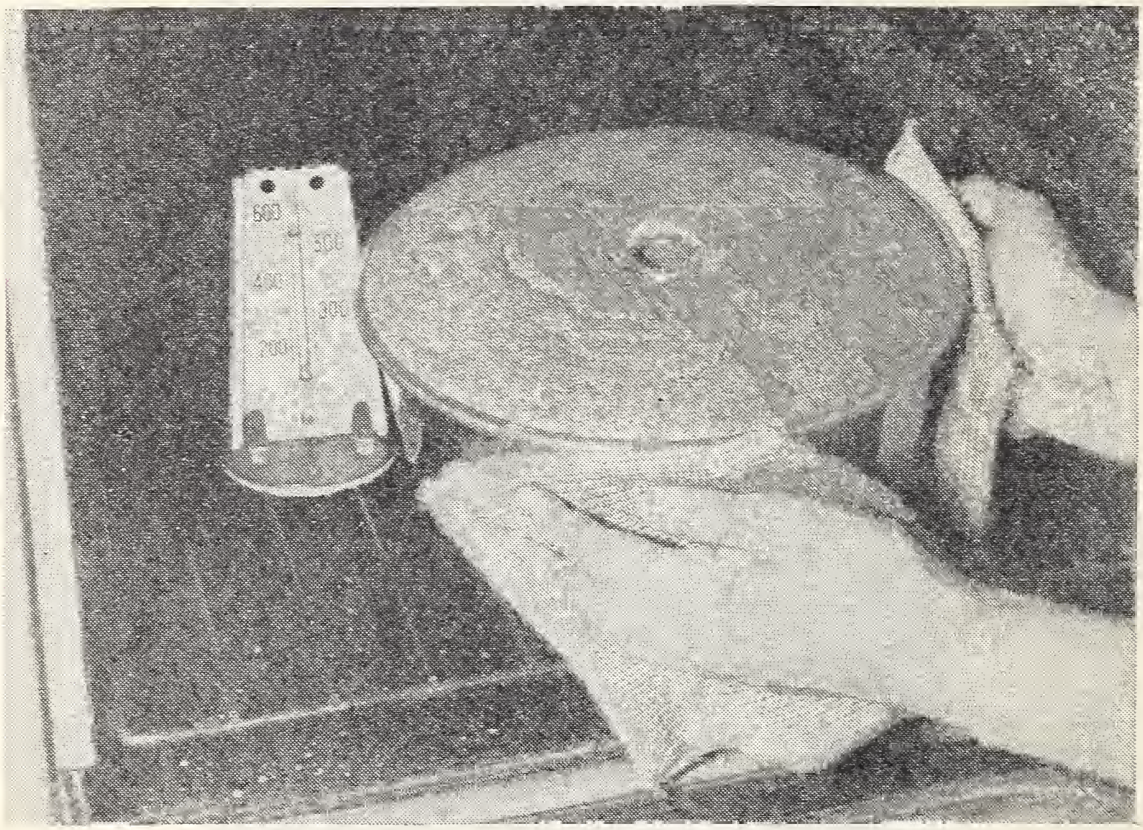

FIGURE 23.—Bake sponge cake in a slow oven (300° F.).

In baking, the same care is required to keep the temperature moderate as in other methods of cooking with eggs (fig. 23). Such a temperature gives the air a chance to expand and give volume to the product before the eggs coagulate, and the interior of the cake becomes set without the outside shrinking and becoming tough. Because of the fat in the yolk used in sponge cake, which makes it more tender, the temperature for baking may be higher than for angel food.

These same principles apply to the methods of making all products in which egg is used as leavening: Care in beating to the right stage of foam, immediate use after beating, care in combining the ingredients with the foam to prevent loss of air, and cooking at a temperature just above coagulation so that the mixture will set in the center without becoming shrunken and tough on the outside, or watery as a result of overcoagulation of the protein.

When other ingredients are added to eggs, as in white-sauce omelets, and vegetable and meat souffles, the eggs are diluted somewhat and slightly higher temperatures may be used without the toughening effect being so noticeable. However, overcooking will cause separation and wateriness of the product.

The addition of acid obtained, for instance, by incorporating tomatoes in omelets or fruit pulp in fruit whips, makes a more tender product owing to the effect of the acid on the egg proteins.

EMULSIFYING WITH EGGS

Egg yolk is useful in forming permanent emulsions, such as mayonnaise, and is more efficient in this respect than egg white or the whole egg. Its emulsifying property is probably due to a compound of protein with lecithin, one of the lipoid or fatty constituents of egg yolk, forming what is called a lecithoprotein.

Mayonnaise is an oil-in-water emulsion in that the oil is dispersed in globules throughout the liquid. Unless the oil globules are surrounded by some substance which clings closely to the surface, the oil will not stay in the form of globules but will run together again and form an oil. If egg yolk is adsorbed on the surface of the fat globules, they do not run together and the emulsion becomes more or less permanent. In order to get the oil into the form of globules it is necessary to agitate it in some way. In home preparation of mayonnaise this is generally accomplished with an egg beater. The oil is broken up into globules in the presence of the egg yolk, so that as soon as they are formed the emulsifying agent is adsorbed quickly.

The addition of the seasonings, such as salt, paprika, mustard, and sugar, to the egg yolk before the oil is added, assists the egg yolk to make a more stable emulsion. The addition of a small quantity of the acid to make a heavy paste is also an advantage in starting the emulsion. The oil at room temperature should be added in very small quantities at first with rapid beating until some emulsion is formed; then it may be added with increasing rapidity. If the oil can be added under the surface of the forming emulsion, a more stable emulsion will be formed. Stopping the beating for each addition of oil seems to be an advantage in that it allows time for the adsorption of the egg yolk on the fat globules.

In food products such as salad dressings, cream puffs, and some types of cakes, other emulsions are formed which no doubt eggs help to stabilize. Since ingredients other than eggs make up an important part of these products, the techniques involved depend on their presence, as well as on that of eggs.

EGGS IN THE MANUFACTURE OF FOOD PRODUCTS [13]

EXTENT OF USE OF DIFFERENT FORMS OF EGGS

Eggs in three forms—in the shell, frozen, and dried—are available to manufacturers of food products. Separated whites and yolks also may be had in liquid, frozen, or dried form. Bakers have long used large quantities of fresh and frozen eggs. By 1932, commercial bakeries were utilizing fresh shell eggs worth more than 11 million dollars in a year, frozen egg whites worth 21 million dollars, and frozen yolks worth 15 million dollars.

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[13] By J. A. LeClerc, senior chemist, and L. H. Bailey, associate chemist, Food Research Division, Bureau of Agricultural Chemistry and Engineering.

It is estimated that in 1939 about one-half of the cost of all the ingredients used by cake bakers was that of eggs or egg products, a total of nearly 50 million dollars. In some bakery products, such as sponge cake, the cost of eggs is fully 70 percent of the total outlay. Large quantities are used in making ice cream, custards, beverages, and candies.

Manufacturers of noodles, whose products are valued at more than 10 million dollars a year, also use large quantities of eggs—especially fresh, frozen, or dried whole eggs and frozen or dried egg yolk—valued at fully 1½ million dollars a year. About 5½ percent of the weight of noodles is made up of eggs.

In recent years the prepared-flour industry has been making notable strides. Dried eggs are largely used as one of the essential ingredients of most prepared mixes.

The quantity of yolk used by the mayonnaise and salad-dressing industries approximates annually some 15 to 20 million pounds. Frozen yolk generally is used for this purpose.

The varied characteristics of yolks and whites make possible their use in the manufacture of hundreds of food products. Freshly broken liquid eggs are used to a considerable extent, but the availability of frozen and dried eggs and their products in quantities makes large-scale utilization of these more convenient. The separation of eggs into yolks and whites, their preservation, and their delivery to bakers, confectioners, and food-specialty manufacturers has become a highly efficient and important industry.

Variations in characteristics of yolks and whites affect the commercial food product during its processing as well as in the final form. The solids of the white are almost entirely protein, and the yolk contains practically all the fat of the egg, present in a finely emulsified state. It is impossible to whip the yolk to a stiff foam, owing not only to the nature of its protein but also to the presence of the fat and the absence of fibrous structure around which air cells can be formed. The vitellin of the yolk is insoluble in water but is soluble in salt solution, and it lacks the aerating ability which characterizes the white.

FROZEN EGGS

One of the best ways of preserving whites, yolks, or mixtures of the two is by freezing them. The ease with which they can be kept in the frozen state, which inhibits growth of bacteria, gives them a dependability desired by the makers of such frozen foods as ice cream, as well as by bakers. Their utilization by food manufacturers has shown a steady increase.

Commercial freezing of eggs began about 35 years ago on a small scale. In 1937 some 225,000,000 pounds of frozen eggs were produced in the United States. Of these, 80,100,000 pounds were whole eggs, 18,600,000 pounds plain yolks, 26,700,000 pounds sugar yolks, 16,200,000 pounds salt yolks, 336.000 pounds glycerin yolks, and about 83,000,000 pounds other products.

CHANGES DUE TO FREEZING

When eggs are preserved at 30° to 32° F., changes take place that affect their physical and colloidal properties. As a result, their functions in cake making, due to their emulsifying, lubricating, and gas-retaining properties, are in some degree impaired. To overcome these defects, the yolks are processed with sugar or other coagulants and frozen at a temperature as low as $-10°$. When frozen and maintained in this condition, eggs undergo no decomposition due to micro-organisms and may be kept for years without loss of vitamin A.

Certain complex physical changes, however, take place. If the white is frozen quickly, the water will be reabsorbed on thawing and the product will revert to its original physical condition. Freezing at low temperatures, however, increases the proportions of thin egg white. If the frozen white is kept for 4 to 5 months, a coagulation of certain protein material of the albumen takes place, and on thawing, white fibers of mucin (not the chalaza) will be visible in the viscous portion of the egg white.

When the freezing is accomplished at extremely low temperature, which is done to prevent biochemical changes, the yolk undergoes a more radical change from a physical-chemical standpoint. It does not revert to the original fluid state but becomes a gummy, rubbery mass, the extent of change depending in part on the length of time in storage. The volume of the thawed product will be less than that of the original material, and the lecithin will have become chemically altered and thereby lose free phosphoric acid. As freezing progresses, ice crystals separate, bringing about an appreciable concentration of the salt of the yolk.

DEFROSTING THE PRODUCT

Defrosting should be done by placing the cans of frozen eggs in a vat of running water. In 5 to 6 hours the eggs will be defrosted and ready for use. Defrosting near the oven subjects that portion of the product near the outside of the can to a temperature of 55° to 60° F. for 15 or more hours as compared with a temperature of 33° to 34° for 5 to 6 hours when defrosting is done in running cold water. In the former case the eggs may become curdled; in the latter, they remain relatively smooth in appearance, retain their fresh flavor, and produce cakes of superior quality. The contents of the entire can should be thawed and thoroughly mixed before use.

Bakers and confectioners should have on hand only as many frozen eggs as they need for current use. Frozen eggs, once thawed or defrosted, are very perishable; therefore, until ready for use they should be stored at a temperature which causes no unfavorable change. To accommodate the smaller establishments, some packers now freeze part of the output in small cans. Bakers should stipulate that all containers of frozen eggs, when received, show evidence that they have not been previously opened and should bear no signs of leakage or sweating. A guarantee should also be required that the contents have not been thawed.

USES AND ADVANTAGES OF FRESHLY BROKEN AND FROZEN EGGS

In baking, frozen eggs behave much like freshly broken liquid eggs and can be substituted for them. Eggs exert a binding action when used in cake making; they are capable of leavening five to six times their weight of other ingredients, thus retaining the air which has been beaten into the mix; they have a considerable emulsifying power; owing to their fat content—one-third of the yolk is fat—they have a shortening action; they improve the flavor of the product, and no substitute has been found that will give the flavor produced by eggs. Furthermore, they give the product a pleasing color. They enhance the cell structure of the product, maintaining it during the baking process, and restrict the vaporization of moisture from the baked product, thus keeping it fresh for a longer period. All these uses add greatly to the appetite appeal. Eggs also add appreciably to the food value.

There is almost no waste in the use of frozen eggs, whereas 3 to 4 percent of the whites may be lost in breaking shell eggs. The former require less space for storage, and there are no transportation charges for the shells and for bad eggs. In frozen eggs, the yolks are firmer and the whites thicker than are the corresponding portions of stored shell eggs. The ammoniacal nitrogen content of whole frozen eggs should not exceed 0.002 percent, of frozen yolks 0.003 percent, and of frozen whites 0.0004 percent.

Commercial frozen whole eggs (sometimes mixed with frozen yolks) are used in doughnut mixes, cake mixes, sweet doughs, jelly bases, cookies, and pastries. Bakers generally use more frozen whole eggs than frozen yolks. Frozen whole eggs may also be used in making omelets, noodles, candy, and mayonnaise. Frozen eggs in some form are an ingredient of most salad dressings, icings, ice cream, food beverages, and certain medicinals. They are used in sweet goods, doughnuts, noodles, mayonnaise, and salad dressings. Yolks have a high food value and greatly improve the color of the product manufactured. They also leaven to some extent, especially when sugar has been mixed with them. Sponge cake and cream puffs made from eggs laid and broken in the spring have a greater volume than if made from eggs laid and broken in the summer.

INDIVIDUAL ADVANTAGES OF WHITES AND YOLKS IN MIXES

Egg yolks are used in cakes in which a deep-yellow color is desired, and are added to whole eggs in mixes to obtain a deeper color or greater emulsifying power. A sponge cake made with egg yolks will have finer cell walls and will hold its cell structure during baking better than an angel food made from egg whites. This is due to the greater emulsifying and stabilizing properties of egg yolks. Some bakers believe that cakes baked with glycerin yolk (yolks mixed with 5 percent of pure glycerin) remain fresh longer than those made without glycerin.

Egg whites, for practical purposes, are about six-seventh water, the rest chiefly protein. They lend little flavor but give a mellowness to the finished cake. They furnish thin but strong walls for the tiny air cells formed when egg white is whipped. Even a small quantity of grease, fat, or egg yolks injures the whipping quality of egg whites.

Frozen whites are used in making angel food, white pound cake, certain kinds of layer cake, box cakes, fruit cake, loaf cake, cup cake, cheese cake, cream icings, cooked marshmallows, meringues, macaroons, and confectionery, especially package goods; also in making white sponge base, applesauce cake, custard pie, white fruit pound cake, and ice-box cookies.

More than 65 percent of the total cost of ingredients used in making angel food is for egg white. For gold cake and pound cake the cost of yolk and whole egg is more than 40 percent. Of the total quantity of ingredients used in making angel food, 40 percent is egg white. In the making of gold cake, 20 percent of the weight of the ingredients is yolk; in pound cake 25 percent is whole egg. Compared with the weight of flour used, egg white in angel food equals 225 percent, yolk in gold cake 83 percent, and whole egg in pound cake 100 percent.

Used in combination with cream of tartar, calcium acid phosphate, or other acid ingredients in making angel-food cake, fresh or frozen egg whites are superior in foaming qualities to the average commercial dried white.

EFFECTS OF VARYING THE QUANTITY OF EGG PRODUCTS IN CAKES

Tests in the Food Research Division indicate that as much as one-third of the egg white in an angel-food cake recipe may be replaced by water without affecting appreciably the quality of the cake. Increasing the egg white by one-third, however, did not result in a satisfactory cake from the standpoint of appearance.

In making pound cake, increasing the quantity of egg in the laboratory formula from one-third to one-half somewhat improved the grain and texture but not the size or general appearance. If the quantity of egg is decreased, as it sometimes is in commercial pound cakes, it is necessary to increase somewhat the quantity of both fat and milk to make a satisfactory product. Occasionally, frozen eggs produce cake of larger volume than do shell eggs, owing probably to the greater uniformity of quality in frozen eggs.

Dried Eggs

ADVANTAGES AND USES

Frozen eggs have recently displaced dried eggs to some extent, but the latter are well suited for use in many processes. The drying of eggs brings them to the manufacturer of food products in convenient form. Elimination of about 90 percent of the water from eggs saves freight charges as well as storage space. Packed largely in strong, light, fiber containers, dried eggs keep well. The products do not appear to be attractive to insect pests. After long storage they may become infested with flour beetles (*Tribolium* spp.), larder beetles (*Dermestes* spp.), and certain dermestids of the genus *Trogoderma*, but no instance of infested dried-egg products has been brought directly to the attention of the Department of Agriculture during the last 10 years. Drying adds about one-tenth to the cost of the eggs. Of the three grades of dried yolk, the flake is the most expensive, followed by spray powder and the granular product.

Smaller quantities of dried eggs than formerly are used by bakers equipped to keep frozen eggs under refrigeration. Furthermore, substitutes at lower prices have displaced the dried product to some extent in the manufacture of art materials. The increasing use of prepared flours offers the chief field of expansion for dried-egg products. Better standardization also promotes their wider use.

Except in prepared materials, dried eggs are used little by the housewife or in restaurants. They are used to some extent by hospitals, hotels, and military establishments, but are best adapted to large-scale usage such as in the manufacture of noodles, macaroni, prepared flours, and prepared ice-cream powders and mixes. Small bakers whose shops lack refrigeration facilities also find dried eggs convenient.

Dried albumen is much used in candy bars and in prepared whipping powders and meringue and by confectioners in making cream centers, nougatines, and marshmallow whips. Fairly good angel-food cakes can be made with dried albumen. A few baking-powder manufacturers for years have been adding small quantities to their product. It is also used in textiles, pharmaceuticals, paper, art paints, and colors. Small quantities also are added to foods for pet animals and birds. Dried yolk, however, is the most important dried-egg product, being used in large quantities in ready-mix doughnut, pancake, and cake flours.

The equivalent of 33 to 41 million dozen eggs per year was consumed as dried eggs in the United States in the 3-year period ending in 1939. Ordinarily only about one-fourth of this amount is domestic production. Disruption of Chinese trade has cut down the imports, but existing plants can take care of domestic requirements. Although they constitute only about 1.6 percent of the national egg consumption, dried eggs have an annual value of approximately 10 million dollars.

RECONSTITUTING DRIED EGGS

Dried egg is uniform in composition and can be reconstituted by addition of water, as follows:

Dried whole egg.—Use 1 part of dried egg to 3 parts of water by weight. Allow the mixture to stand 4 to 5 hours, or until normal liquid-egg consistency is obtained.

Dried yolk.—In reconstituting this product, 2 to 3 parts of water are required for 1 part of yolk. Allow the mixture to stand 1 hour.

Unfermented albumen.—Mixing 1 part of dried albumen and 6 to 7 parts of water will produce a product similar to fresh whites. Allow the mixture to stand 3 hours.

Fermented albumen.—Add 1 part of dried albumen to 10 parts of water. Allow the product to stand 3 hours.

All reconstituted egg products should be used as soon as possible, as they are comparable to fresh eggs and are, therefore, very perishable.

A whipping test may be used to determine the practical value of reconstituted dried white. In testing unfermented white, 1 ounce of the dried product is mixed with 7 ounces of water; with the fermented white, the proportion is 1½ ounces to 15 ounces. After standing for 3 hours, unfermented-white mixtures are beaten in a 10-quart mixer for 2 minutes at second speed and 4 minutes at high speed, and fermented-white mixtures, 1½ minutes at medium speed and 1½ minutes at high speed. Judgment of the value of the dried whites is based on the behavior of the beaten material or foam.

To test its quality, level the beaten foam. Measure the depth with a gage or ruler. Ordinarily, a whip of 6 to 9 inches is obtained. A measurement of 6½ inches or more is considered "fancy"; less than 6 inches, a poorer grade.

Another test of its quality is to break a handful of the foam and examine for texture. A good foam gives a clean break, and the structure is firm. If a crackle is heard the body will not hold up. A drip test may also be made as a measure of the strength of the foam body. A weighed amount of foam is placed in a funnel, and the time required for the first drop of liquid to come through is recorded. A high-grade product has little or no drip.

Manufacture of Noodles and Other Products

Noodles will contain the proper amount of egg solids if the following quantities of egg are used with every 98 pounds of flour: Commercial liquid whole egg, 19 pounds 8.4 ounces; commercial liquid yolk, 13 pounds 11.5 ounces; commercial dried whole egg, 5 pounds 7.4 ounces; commercial dried yolk, 5 pounds 5.5 ounces.[14]

Unless noodles are labeled "plain" or "water" noodles, they are required to contain at least 5½ percent by weight of egg solids. Whole egg, yolks, or mixed yolk and white may be used. An 8-ounce package of "egg noodles" contains about the equivalent of one whole egg. Noodles are, like macaroni, "energy food" rather than a large source of body-building proteins. In buying noodles, the label is more important than the color of the product or the color of the wrapper. Although the United States is second in the manufacture of noodles, macaroni, and similar paste products, Americans consume per capita only about one-tenth as much as the Italians do.

Mayonnaise was first made commercially in the United States in 1906, and its growth as a commercial product has been rapid. Statistics show that in 1937 more than 9 million gallons of mayonnaise were made by 71 companies, representing 80 percent of the industry. More than half a million cases of eggs were required to produce the Nation's annual supply of mayonnaise. Salad dressings and related products on the market also have egg yolk as one of their constituents. Most manufacturers use egg yolks, although a few use whole eggs. Frozen yolks are generally favored for making mayonnaise. Dried yolks are not used by the mayonnaise manufacturers because yolk oil tends to become rancid.

Special frozen-egg products are available to the mayonnaise manufacturer. They are made from selected fresh eggs, separated in sanitary plants, and treated by special processes to prevent the multiplication of micro-organisms during the time the products are allowed to thaw out in the mayonnaise plant and also to enhance the emulsifying properties of the yolk.

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[14] The method for the detection of whole egg or of egg yolk, and for the estimation of the quantity of these egg products used in the manufacture of noodles, is described fully in the Journal of the Association of Official Agricultural Chemists, v. 7, p. 407, and in Cereal Laboratory Methods of the American Association of Cereal Chemists, ed. 3, p. 93.

Ice creams and the better classes of sherbets contain beaten eggs to keep the ice crystals apart. Whites of eggs are commonly used, but whole eggs or egg yolks give nutritive value as well as color and flavor to ice-cream products. When eggs are not included, ice cream tends to freeze in a solid block. Custards, pies, and pastries usually contain eggs. Recipes for meat loaves, dressings, sauces, puddings, beverages, dumplings, and soups may call for the use of eggs.

Like most home-made candies, great quantities of commercial chocolates, nut candies, and other popular confections contain eggs. Candy manufacturers in the United States use fresh eggs and frozen-egg and dried-egg products aggregating millions of pounds every year. The admixture of egg foams prevents the sugar crystals from gathering into hard lumps, hence egg products are sometimes called interfering agents. When dried eggs are employed in candy making they are ordinarily reconstituted with water—restored to their liquid form—before being used.

WEIGHTS AND MEASURES OF VARIOUS FORMS OF EGGS

Shell eggs, in quantities of 100 pounds, yield 10 to 12 pounds of shell, 58 to 60 pounds of white, and 30 to 32 pounds of yolk. Table 4 shows the quantities of each obtained from 100 eggs of the sizes indicated.

TABLE 4.—*Quantity of egg materials produced from 100 eggs of different sizes*[1]

Eggs per pound (number)	Liquid eggs				Dried eggs		
	Yolk	White	Whole egg	Shell	Yolk	White	Whole egg
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
7	3.99	8.88	12.87	1.41	1.88	1.25	3.77
8	3.66	7.58	11.24	1.25	1.72	1.07	3.29
9	3.44	6.55	9.99	1.12	1.62	0.92	2.93
10	3.28	5.69	8.97	1.04	1.55	0.80	2.63
11	3.19	4.94	8.13	0.95	1.50	0.69	2.38

[1] The data are computed on the basis that 1 pound of dried egg is from 3.41 pounds of liquid whole egg, 7.12 pounds of liquid whites, or 2.12 pounds of liquid yolk.

A case of 30 dozen eggs weighs about 42 to 43 pounds net and yields approximately 35 pounds of liquid whole egg. On an average, 100 pounds of shell eggs produce commercially about 84 pounds of liquid whole egg. Twenty whole eggs, 36 whites, or 48 yolks make 1 quart of product. The liquid egg from 9 to 11 shell eggs will weigh about 1 pound, and 17 to 20 whites or 19 to 22 yolks weigh 1 pound. One pound of dried eggs can be made from 39 liquid eggs; 1 pound of dried yolk, from 48 yolks; and 1 pound of dried albumen, from 70 whites.

PHYSICAL AND CHEMICAL COMPOSITION OF EGGS[15]

In keeping, processing, and utilizing eggs, their physical and chemical composition must be considered. It has already been indicated in this circular that the structure of eggs, strength of shell, tendency to increase in alkalinity, as well as the susceptibility to bacteriological infection, are important factors in all steps of handling and storage. The composition of eggs is the key to many of their uses.

PHYSICAL COMPOSITION

The physical make-up of eggs (table 5) varies more than their chemical composition. This variation is due to one or more of several factors, the most important of which are age, diet, breed, and inherited characteristics of the chicken. Occasionally there is as much variation between eggs of the same chicken as there is between eggs from different chickens.

In eggs ranging in weight from 1.8 to 2.1 ounces (50 to 60 grams), the weight of the component parts may vary, but the percentage composition, that is, the ratio of white to yolk, remains fairly constant and is consistent with values given for an average 2-ounce egg. In eggs weighing less than 1.8 and more than 2.1 ounces, there is a tendency for the percentage of yolk to decrease and the percentage of white to increase.

TABLE 5.—*Physical composition of eggs*

Egg weight (grams)	Total contents		White			Yolk			Shell and membrane	
	Weight	Percentage of egg weight	Weight	Percentage of egg weight	Percentage of weight of egg contents	Weight	Percentage of egg weight	Percentage of weight of egg contents	Weight	Percentage of egg weight
	Grams	*Percent*	*Grams*	*Percent*	*Percent*	*Grams*	*Percent*	*Percent*	*Grams*	*Percent*
[1] 55 6	50.0	89.9	31.4	56.5	62.8	18.6	33.4	37.2	5.6	10.1
[1] 56.0	49.7	88.7	33.4	59.6	67.2	16.3	29.1	32.8	6.3	11.3
[2] 56.7	51.4	90.7	33.1	58.4	64.4	18.3	32.3	35.6	5.3	9.3
[3] 57.1	50.2	87.9	32.1	56.2	63.9	18.1	31.7	36.1	6.9	12.1
[4] 56.3	50.3	89.3	32.5	57.7	64.6	17.8	31.6	35.4	6.0	10.7

[1] Average of several breeds. [2] Rhode Island Red. [3] Breed unknown. [4] Average.

The proportion of yolk to white is practically independent of the layer's diet, and the proportion of shell is not affected by the type of feed, provided the layer receives the minimum requirement of vitamin D, calcium, and manganese. However, size of eggs is affected to some extent by the nature of the diet. Hens also may be fed for the production of yolks of lighter or darker hue. Experimentally, hens have been so dieted as to produce practically white yolks. Despite the several factors that may affect their eating quality, chicken eggs as laid have a remarkably uniform goodness.

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[15] By Charles A. Denton, junior chemist, Animal Nutrition Division, Bureau of Animal Industry.

Chemical Composition

The chemical composition of normal chicken eggs varies so little that for practical purposes it may be considered constant. The trade is interested in the chemical properties because of their bearing on the keeping of eggs; the dietitian, because of their relationship to food values and their significance in preparation of foods.

SHELL AND MEMBRANE

The eggshell contains about 1.66 percent of protein but is made up largely of inorganic compounds, principally calcium carbonate. Although the percentage composition of the shell and its contents is not materially affected by a deficiency of calcium in the diet of the chicken, the shell tends to become thinner as the deficiency becomes more pronounced. Among other elements found in small quantities in the shell are phosphorus, magnesium, lead, iron, and strontium. A proximate chemical analysis of the shell gives the following average results: Water, 1.46 percent; organic substance, 4.2; ash, 55.33; calcium, 37.8; phosphorus, 0.2; and magnesium, 0.4. The shell membrane usually constitutes about 4.5 percent of the combined weight of shell and shell membrane.

TOTAL CONTENTS

Small differences in the percentage of protein in the dry matter of the whites and yolks of eggs from chickens receiving diets with different protein supplements have been reported. However, no conclusive evidence has been presented to show that the diet of layers has any marked effect on the composition of the proteins of their eggs. The addition of calcium and magnesium to the diet and the feeding of iron and copper supplements do not materially affect the quantities of these elements in the egg contents. Addition of 2 percent of cod-liver oil to the diet brings about an increase of iron and copper content of the yolk. Lead, fluorine, selenium, and iodine added to the diet result in increases of these minerals in the eggs.

The chemical compositon [16] of the total contents, as averaged from many analyses, is as follows: Water, 73 percent; protein, 13.3; fat, 11.5; nitrogen-free extract, 1.1; free sugar as glucose, 0.3; ash, 1; potassium, 0.15; sodium, 0.16; magnesium, 0.01; calcium, 0.05; iron, 0.0027; sulfur, 0.23; phosphorus, 0.21; chlorine, 0.18. Minor constituents include aluminum, zinc, copper, lead, fluorine, iodine silicon, arsenic, boron, chromium, rubidium, strontium, titanium, and vanadium.

EGG WHITE

The proportion of fluid and firm white in the egg varies considerably. One group of investigators reports the outer fluid white to be 20 to 55 percent; firm white, 27 to 56 percent; and inner fluid white, 11 to 36 percent. The percentage of firm white appears to depend on the inherited characteristics of the layer and is not essentially influenced by diet. The difference between the firm and fluid white seems to be due chiefly to a difference in mucin content. The ratio of mucin content of the firm white to that of the fluid white is about 9:1.

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[16] Percentage figures for calcium, phosphorus, iron, and chlorine in whole egg, white, and yolk were prepared by Charlotte Chatfield, Food and Nutrition Division, Bureau of Home Economics.

Five different proteins, of which albumin constitutes about 69.7 percent, are present in egg white. The other proteins are conalbumin, 9.0 percent; globulin, 6.7; mucoid, 12.7; and mucin, 1.9.

The average chemical composition of the white is as follows: Water, 86 percent; protein, 11.6; fat, 0.2; nitrogen-free extract, 0.8; free sugar as glucose, 0.4; ash, 0.8; potassium, 0.15; sodium, 0.16; magnesium, 0.011; calcium, 0.006; iron, 0.0002; sulfur, 0.212; phosphorus, 0.017; chlorine, 0.18. Minor constituents of white include aluminum, manganese, zinc copper, lead, fluorine, iodine, and silicon.

EGG YOLK

The two chief proteins in the yolk are vitellin and livetin, the former comprising approximately 78 percent and the latter approximately 21 percent of the total protein. Except for small traces in the white, all the fatty materials of the egg are found in the yolk.

The average chemical composition of egg yolk is about as follows: Water, 49 percent; protein, 16.7; fat, 31.6; nitrogen-free extract, 1.2; free sugar as glucose, 0.21; ash, 1.5; potassium, 0.113; sodium, 0.049; magnesium, 0.017; calcium, 0.147; iron, 0.0072; sulfur, 0.2; phosphorus, 0.59; chlorine, 0.17. Minor constituents include aluminum, manganese, zinc, copper, lead, fluorine, iodine, and silicon.

Color and Color Preferences

Two pigments have been found in eggshell, namely, oörhodein, a red-brown pigment believed to be the same as hematoporphyrin, and oöcyan, a blue-green pigment believed to consist in part of the bile pigment biliverdin.

The green-yellow pigment of egg white is d-riboflavin (vitamin G). This appears to be the only pigment normally present in the white.

The carotenoid pigments of the yolk may consist of a number of carotenols, among which commonly are xanthophyll, zeoxanthin, cryptoxanthin, and occasionally capsanthin. The two chief pigments normally present are xanthophyll and zeoxanthin, the ratio being 7:3. Cryptoxanthin may comprise from 3 to 9.5 percent of the carotenoid content of the yolk, depending on the amount of pigment present in the diet. Capsanthin, when present in the diet, is deposited to about the same extent as cryptoxanthin. Carotene is found in only very small quantities in the yolk. The color of the yolk can be changed from a pale yellow to a bright red (values 6–22 on the Heiman-Carver yolk-color roter), depending on the amount and type of pigment present in the diet.

Color of shell makes no difference in the food quality of eggs. It does, however, affect price in certain markets, for some regions prefer white and other regions brown-shell eggs. Many consumers are willing to pay as much as 4, 5, or even 10 cents a dozen more for eggs which satisfy their demand for a certain color of shell and for a light or dark yolk. Official grades in some markets take the local preferences into account, and the producer and trade must meet the color requirements to place eggs in the top grades. The shell color is a question of breed, the yolk color one of feed.

There is not necessarily any connection between the color of the shell and the yolk, and there is no foundation, with respect to quality, for discrimination against color of shell or against medium- to dark-yolk eggs. Consumer preferences are based primarily on custom, and the markets are far more likely to try to supply the buyers with what they want than to attempt to change their tastes. However, surveys show that these preferences do not constitute deep-seated prejudice against any normal color. A survey[17] in which more than 10,000 persons were asked to express their preference for eggs with light, medium, and dark yolks, and with brown and white shells, sample colors of which were shown for their inspection, resulted in the following response: Slightly more than one-third of the consumers interviewed preferred the light yolks, one-fourth the dark yolks, about one-fifth the medium yolks, and one-fifth had no preference. Slightly less than one-half preferred white shells. On the basis of these findings, in large areas where producers cannot afford to exchange their home-grown feeds for those which will produce lighter yolks, it may be possible for the producers, working together, to educate customers to use more eggs with highly colored yolks.

EGGS AND MICROBIOLOGY[18]

The influence of micro-organisms on the keeping quality of eggs and egg products has received considerable study, because much of the deterioration in fresh, stored, and processed eggs results from the growth of bacteria and molds. The finding of large numbers of bacteria in eggs is an indication of improper handling and often of insanitary conditions. Eggs are a medium in which bacterial multiplication can take place rapidly, and for this reason it is necessary that they be handled with speed and under as sanitary conditions as possible, if high quality is to be maintained. This statement applies to all phases of the egg industry, from the handling of the flock to the final use of the eggs.

New-Laid Eggs Usually Free From Bacteria

The contents of normal new-laid eggs as a rule contain no bacteria. Normally the shell prevents contamination, but under conditions of high moisture and in the presence of dirt and filth bacteria enter eggs through the shell. The normal freedom from bacteria is borne out by the fact that clean, infertile eggs seldom undergo bacterial decomposition in an incubator or during storage.

Through infection of the ovary or oviduct, a small percentage of eggs contain bacteria at the time they are laid. Investigators state that the percentages of bacterial infection in fertile and infertile eggs are essentially the same and that no hen lays all bacteria-free eggs during any full year. Sharp[19] indicates that bacteria in eggs are present either in large numbers or not at all. He also states that not more than 1 or 2 percent of eggs properly cared for are infected with micro-organisms.

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[17] THOMSEN, F. L., and WINTON, BERLEY. CONSUMER PREFERENCE FOR EGG YOLK COLOR AND SHELL COLOR IN NEW YORK CITY. Mo. Agr. Expt. Sta. Bul. 329, 23 pp., illus. 1933.

[18] By Harry E. Goresline, senior bacteriologist, Food Research Division, Bureau of Agricultural Chemistry and Engineering.

Egg white is germicidal to a number of types of micro-organisms, including pathogenic types, but it loses most of this power after long storage. The name "lysozyme" has been given to this germicidal agent, which is found in the white of eggs, and its action has been studied by many workers. It is probable that more eggs would have bacterial infection if it were not for this protective substance. It apparently prevents infection through the shells, but loses its potency as eggs lose most of their natural carbon dioxide. Therefore, rapid deterioration of eggs and egg products is largely the result of improper handling at some stage and not of initial infection.

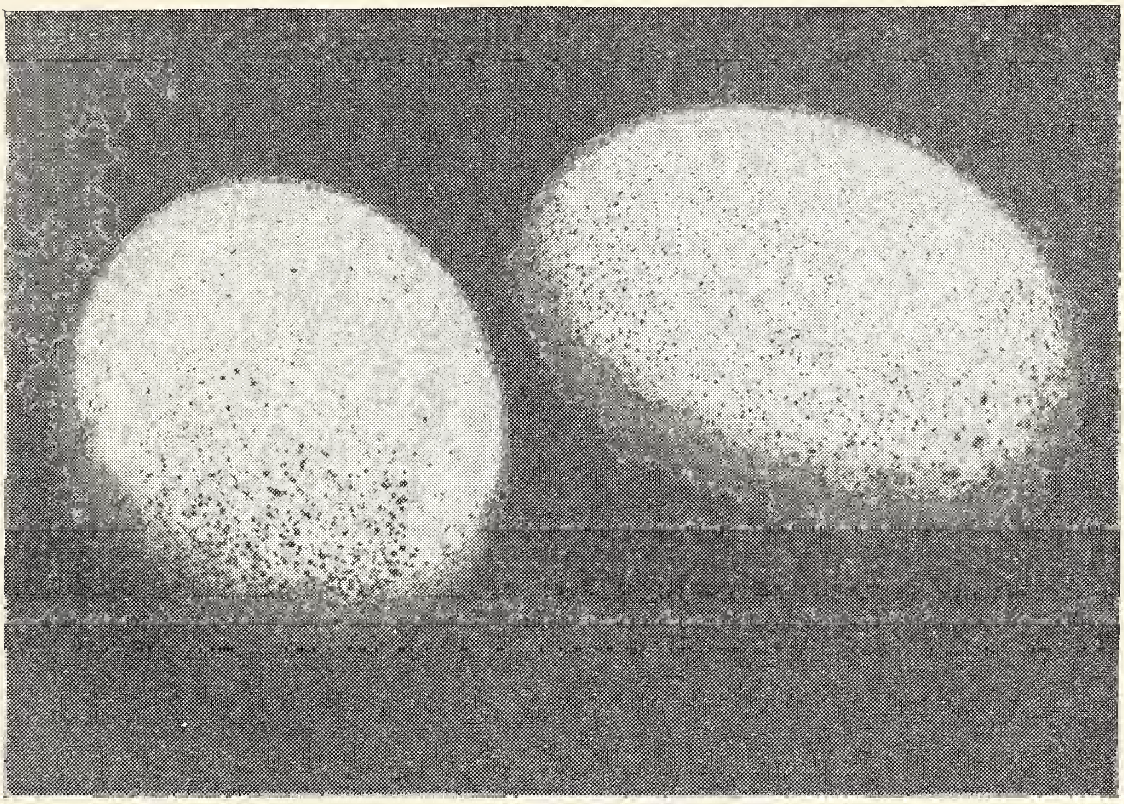

FIGURE 24.—Egg pores. These shells were scraped and dyed inside. The dye, working through, made the pores plainly visible.

IMPORTANCE OF PROPER CARE AND STORAGE

The care and storage of shell eggs govern to a large extent the quality of the final product. Many eggs classed as "dirties" have been found to contain bacteria after incubation. There is also considerably greater loss of dirty eggs than of clean eggs when they are removed from storage and allowed to sweat. The bacteria probably gain access to eggs through the few large pores of the shell (fig. 24).

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[19] SHARP, PAUL F. PRESERVATION AND STORAGE OF HENS' EGGS. Food Res. 2 : 477, illus. 1937.

The humidity of the air during storage is an important factor in the bacterial penetration of the shell of dirty eggs and of those that have been washed.

Bacteria increase very rapidly at ordinary room temperatures. For this reason it is essential to store eggs in a cool place as soon as possible after they are laid and to sort them carefully in order to eliminate sources from which infection can spread to good eggs.

The main types of bad eggs found during and after storage are green white, digested whites, and white, red, and black rots, and musty eggs. As a rule these types show decided chemical decomposition and are heavily infected with bacteria. Of the species of bacteria that have been detected, many were the direct cause of egg spoilage whereas others were only incidental to the infections. Species of *Pseudomonas* and *Achromobacter* have been reported as causing mustiness in eggs. Several types of bacteria cause rots. Fortunately, nearly all infected eggs may be detected by candling.

Much of the pin-spot molding of eggs appears to be caused by the use of green shook in the making of egg cases and the use of old fillers. These materials provide ideal conditions for the germination of mold. Sharp and Stewart [20] give the optimum humidity of 96 to 100 percent for the development of this mold at 30° F., and state that meager white hyphae or "whiskers" 1 to 2 millimeters long may appear at 90 percent humidity. The white growth on the shell increases the mold infection of the contents of eggs if they are held in storage too long and may cause darkening on the inside of the shell.

In egg-breaking plants, it is important that any container touched by spoiled egg substance be thoroughly cleaned and sterilized before it is used again. One bad egg, if it is not eliminated at the time of breaking, can act as "seed" for infecting a whole batch of eggs which have been broken out.

Certain bacteria cause mustiness, and the odor and flavor are extremely penetrating. One musty egg may render large quantities of material unpalatable even though all the precautions of rapid handling and low temperatures are observed. This is why it is so important that each egg should be broken and observed separately. Broken-out egg material should be frozen as soon as it can be removed from the churn or mixer, and the frozen product kept solidly frozen at all times to hold the bacterial count to a minimum.

Bacteria increase in numbers by dividing into 2 individuals. Under certain conditions this takes place every 20 to 30 minutes. If division at 30-minute intervals is assumed, then 1,000 bacteria become 4,000 at the end of 1 hour, 16,000 at the end of 2 hours, and more than 250,000 at the end of 4 hours. Within reasonable limits, the higher the temperature the faster bacteria grow, and the lower the temperature the slower the increase in numbers. The growth of bacteria is markedly retarded at temperatures of about 40° to 50° F. (refrigerator temperature) and is nearly stopped at the freezing point of water (32°).

Almost the sole exception to maintenance of minimum bacterial counts is in the preparation of dried albumen by the fermentation process. The egg white used in this product must, of course, be up to the usual standards of quality and freedom from objectionable kinds of bacteria. A marked difference in original quality of eggs is reflected in the report by De Bord,[21] in which the bacterial counts of experimentally spray-dried whole eggs were 350 for good eggs as compared with 1,160,000 for bad eggs. Good material, sanitation, rapid handling, cold temperatures, and constant inspection should be watchwords in an egg-breaking plant.

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[20] SHARP, PAUL F., and STEWART, GEORGE F. EFFECT OF RELATIVE HUMIDITY ON THE GROWTH OF MOLD ON EGGS IN STORAGE. N. Y. (Cornell) Agr. Expt. Sta. Mem. 191. 11 pp., illus. 1936.

The significance of bacteria in eggs and egg products with regard to public health has never been fully established, although many types have been isolated and studied from the standpoint of spoilage, sanitary significance, and epidemiology. *Escherichia coli* is naturally present on the surface of eggshells, and some contamination is to be expected in broken eggs, but the presence of such bacteria in large numbers may be taken as an indication of lack of sanitation in the egg-breaking plant.

Cases of food poisoning from eggs have been reported from England.[22] Most of these were *Salmonella* types of poisonings from duck eggs and the use of raw whipped whites. The attacks are rare, indicating a low percentage of infected eggs. The possibilities of human infection through eggs or food products made with eggs should be taken into consideration, and in order to eliminate such danger, the best sanitary methods in food handling should be employed.

FROZEN-EGG PRODUCTION [23]

The preparation of frozen-egg products is now universally recognized as an excellent means of conserving eggs. Freezing prevents decomposition and minimizes deterioration for an extended period of time, thus preserving the original quality of eggs until they are required for use.

Eggs laid from February through May, because of their greater volume and the firmness of their whites, are considered superior in quality to those laid from June through September. Since egg production occurs on a seasonal basis, freezing affords an efficient means of preserving eggs for use throughout the year. The condensed nature of frozen products as compared with shell eggs results in lower costs of packing and transportation and less loss of material. The freezing of eggs is primarily an American industry centering in the Grain Belt and along the Pacific coast.

Growth of the Industry

In the early history of the frozen-egg industry, breaking stock consisted largely of eggs unsuitable for shipment and storage as shell stock, that is, dirty, cracked, thin-shelled, weak-membraned, or undersized eggs. Although the development of the freezing process offered a byproduct outlet for eggs which otherwise were nearly a total loss, the use of poor-quality breaking stock prepared under insanitary conditions, together with the fact that some of the more unscrupulous dealers included eggs of questionable character, retarded early progress of the industry.

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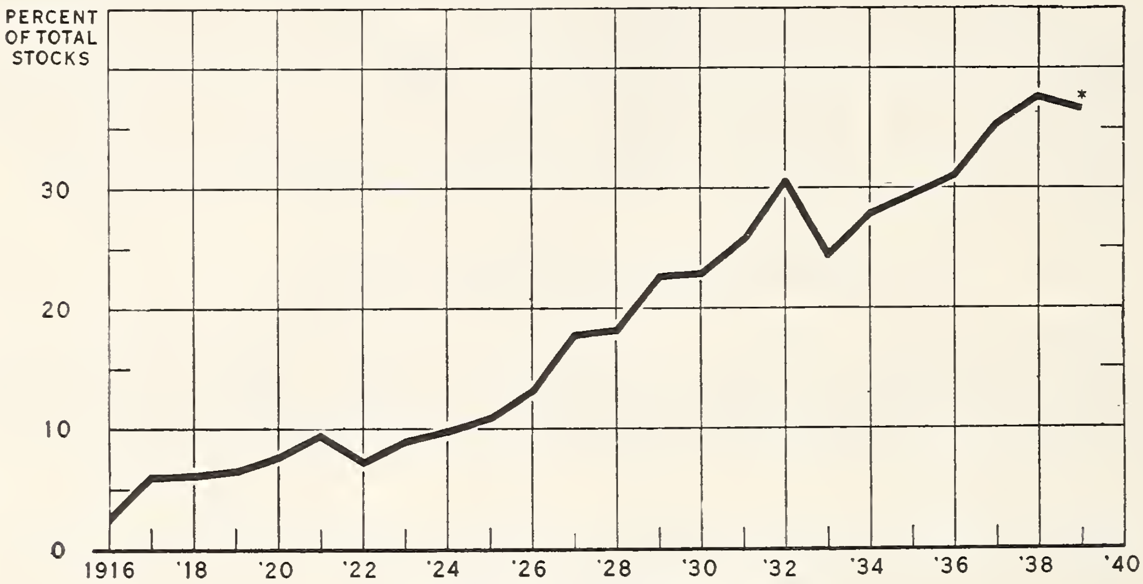
[21] De Bord, George G. effect of dehydration upon the bacterial flora of eggs. Jour. Agr. Res. 31 : 155–164. 1925.

[22] Scott, W. M. food poisoning due to eggs. Brit. Med. Jour. 1930 (3627) : 56–58. 1930.

[23] By Roy Schneiter, assistant bacteriologist, Bacteriological Division, Food and Drug Administration.

Development of the frozen-egg industry has been attributed primarily to changing modes of living. A decrease in the amount of home baking has resulted in a corresponding increase in the consumption of goods produced by commercial bakeries. The demand for high-grade frozen eggs to be used in the manufacture of dressings, frozen foods, and bakers' and confectioners' goods has become so great that packers find it profitable to use large quantities of sound, fresh, wholesome eggs of uniform consistency, for these purposes. Clean, sound, wholesome shell stock is essential in the preparation of good frozen-egg products.

Rapid growth in the industry is reflected in the increasingly larger proportion of total egg-storage holdings represented by frozen eggs from 1916 to 1939, as shown graphically in figure 25.[24] Table 6 also shows the increasing importance of frozen-egg products.



* ESTIMATED FROM STORAGE HOLDINGS OF JULY 1

FIGURE 25.—Growth of frozen-egg industry in the United States. Frozen eggs as percentage of total storage stocks on August 1, 1916–39.

TABLE 6.—*Production of frozen eggs each year during the period 1921–39* [1]

Year	Total frozen-egg products	Shell-egg equivalent	Year	Total frozen-egg products	Shell-egg equivalent
	Million pounds	*Million cases*		*Million pounds*	*Million cases*
1921	46	1.3	1931	152	4.3
1922	49	1.4	1932	138	3.9
1923	71	2.0	1933	171	4.9
1924	57	1.6	1934	198	5.7
1925	79	2.3	1935	206	5.9
1926	92	2.6	1936	208	5.9
1927	129	3.7	1937	225	6.4
1928	148	4.2	1938	116	3.3
1929	155	4.4	1939	177	5.1
1930	185	5.3			

[1] 1921–36 unpublished estimate by United States Tariff Commission, based on original entry into cold storage; 1937 estimate by Agricultural Adjustment Administration; 1938 and 1939 estimates by Agricultural Marketing Service.

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[24] RADABAUGH, JAMES H. ECONOMIC ASPECTS OF THE FROZEN-EGG INDUSTRY IN THE UNITED STATES. World's Poultry Cong. and Expo. Proc. 7: 364–367, illus. 1939.

Types of Frozen-Egg Products

There are three types of frozen-egg products—whole mixed eggs, in which the yolks and whites are made into a fairly homogeneous mass, frozen yolks, and frozen whites. Salt, sugar, and glycerin are sometimes added to egg yolk before freezing if the finished product is to be used for special manufacturing or baking purposes. These substances are employed as anticoagulants. When egg-yolk batter is frozen without the addition of a protective agent and egg structure is broken down, the thawed batter is likely to have a wattery and ropy consistency. This condition has been found to be due to the dehydration and coagulation of a yolk substance, lecithoprotein.

Egg yolk may be described as a mixture about half water, the remaining half consisting of fat, protein, lecithin, and small quantities of other solids. As the mixture chills, some water separates from the solids and collects in localized spots. As chilling progresses to freezing, still further separation takes place. This separation in slow freezing, when no anticoagulant is used, causes a change in appearance of the batter. The mass begins to show ice crystals and small leatherlike lumps of separated egg solids, which form a core in the center of the mass as complete freezing occurs. Cans of yolks which have this core often thaw slowly and seldom become satisfactorily reconditioned. The resulting lumps lower the emulsifying quality of the yolks and are likely to cause yolk specks in the finished product in which they are used. Such a product also spoils easily.

Efforts have been made to prevent core formation, either by speeding up the rate of chilling and freezing or by the addition of some soluble and edible materials, such as salt, sugar, or glycerin, to lower the freezing point of the water content of the yolks, thereby checking its separation from the solids. These added substances may also inhibit bacterial growth and enzyme activity. Soluble materials added must not be of such nature that they impair the quality of any of the yolk constituents contained in the egg solids, nor should they be added in an attempt to improve an inferior product.

Handling Shell Eggs at Breaking Plant

To maintain their freshness, it is necessary that shell eggs be placed in cold storage as soon as they are received at the breaking plant. Adequate chilling of shell stock before breaking also tends to harden the whites, thus facilitating better candling, grading, and separating operations. Thoroughly chilled eggs are also less likely to decompose during the breaking and freezing processes.

Case lots of shell eggs should be transferred from the storage compartments to the candling room only as needed in the breaking plant. For reasons given previously, it is important that all dirty and defective eggs be segregated and removed for breaking in a separate operation. Also, before dirty eggs are broken it is advisable that their shells be washed.

As shell eggs are candled and graded at the breaking plant, they are usually placed in 12-quart galvanized-iron pails and carried by hand or by mechanical conveyor to the breaking tables. In some plants containers are dispensed with and the eggs are placed directly on traveling belts. This system is desirable on account of its sanitary features. The conveyor belt, during its return journey from the breaking to the candling room, can be passed through a cleaning and sterilizing bath, where rotating brushes thoroughly scrub the surface to remove any traces of dirt, and a series of rubber rollers and a current of air dry it.

Breaking and Separation Processes

Egg breaking is not an automatic mechanical process. Approximately 2 percent of expertly candled eggs contain imperfections which are likely to pass undetected unless the eggs are broken by trained inspectors. Sight and smell examination (for appearance and odor), supplemented, if necessary, by a bacteriological analysis, has been found to be the most reliable method for the detection of decomposed material. The problem of separating the egg meats from the shells has also thus far defied machine builders.

Egg breaking is done by hand, usually by women who soon become accustomed to the work and attain high working speed. Eggs are broken against a blunt knife mounted horizontally, edge uppermost, at a height of 6 to 8 inches above a small tray. The trays are supplied with two to four cups, each capable of holding the yolks and white of about three normal eggs. A cup is placed beneath the knife, and the operator rapidly breaks three eggs and allows the meats to fall into the cup below. The filled cup is then pushed aside, replaced with an empty one, and the process repeated.

The operator discards any egg visibly unfit. When all cups on the tray are filled, she smells the contents of each in turn to detect any musty or abnormal eggs which may have passed the candling test. If all eggs are fresh, the contents of the cups are poured into a large pail placed conveniently at the side of the operator. The object of the small cup is to reduce loss caused by the inclusion of musty or abnormal eggs. One such egg would quickly taint a pailful. Since no more than three eggs are broken into each small cup, the loss caused by each musty or abnormal egg, if detected at this stage, can be no more than that of two sound ones. Whenever musty or abnormal eggs are encountered during breaking, all equipment coming in contact with them should be thoroughly washed and sterilized and the hands of the operator washed before breaking operations are resumed.

Two methods are commonly employed for the disposal of the shells and abnormal eggs. Egg-breaking tables are generally constructed with large vents or openings by each breaker. Shells and abnormal eggs are discarded through these vents into large cans or spiral screw-type mechanical conveyors. The latter method is preferable since it insures continuous removal of refuse, thus aiding in maintaining a plant free from flies and undesirable odors. Some manufacturers have also developed useful byproducts from the shells and other breaking-plant refuse.

If yolks and whites are to be canned separately, they must be separated during the breaking process. This is accomplished by means of a sliding, hinged separator, which is attached to the breaking knife. The separator consists of two parts—a receptacle about the size of an egg yolk and a sharp-edged ring just large enough to fit over the yolk. This ring may be raised and lowered so as to cut the white from the yolk resting in the receptacle (fig. 26). The severed white falls into a small cup and the receptacle is then tipped to one side, causing the yolk to drop into another cup. The contents of each cup are carefully inspected for odor and appearance before they are emptied into larger containers. An egg with a weakened or ruptured vitellin membrane cannot be satisfactorily separated into yolk and white components.

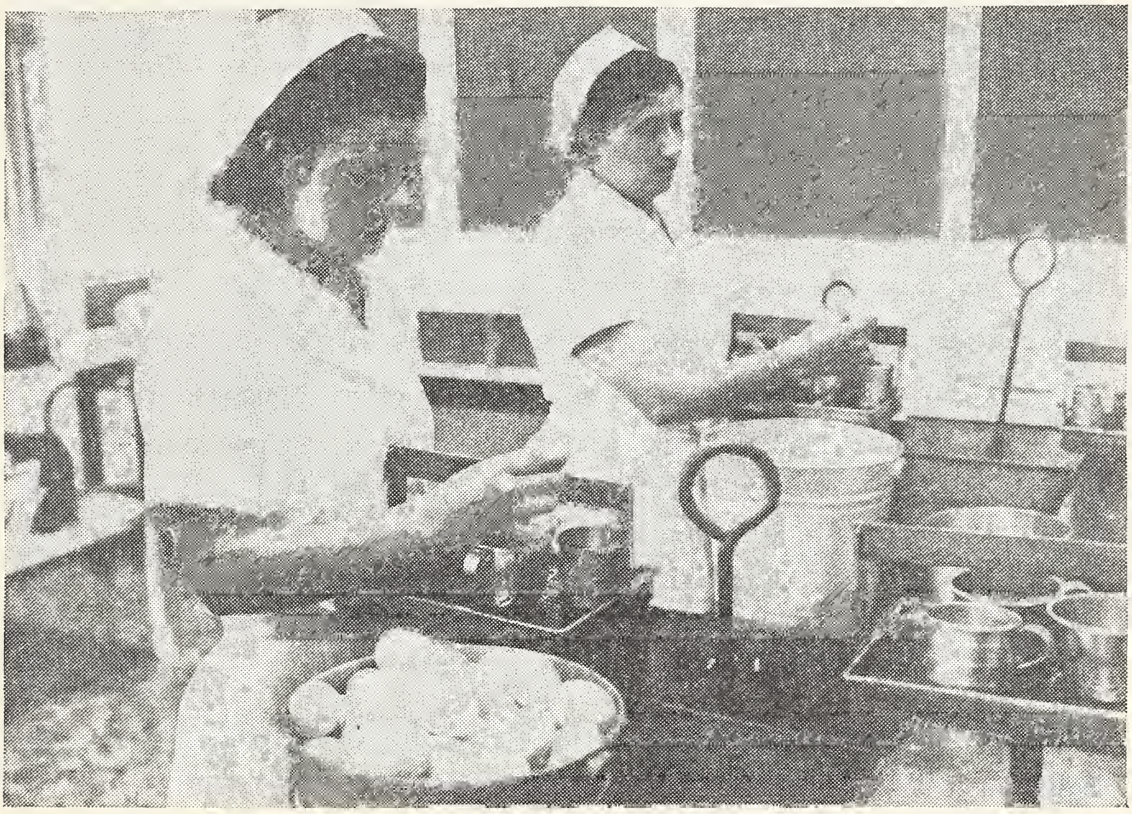

FIGURE 26.—Sanitary breaking trays, showing cups and breaking knives. Operator at right breaks egg into a small cup equipped with a hinged ring separator that is pressed down over the egg to cut away the egg white. Most of the white falls into one cup and the yolk is emptied into another.

CANNING, FREEZING, AND STORAGE OF EGG BATTER

Liquid whole eggs and liquid yolks are lumpy and viscous. Therefore, it is essential that they be processed by some method which will crush yolk skins and remove particles of shell and other lumpy materials. Excessive agitation of the whites results in foaming and must be avoided. Liquid eggs are processed in breaking plants by various methods which may be classed into four general types: (1) Churning in motor-driven mixers, (2) pressure-grinding plus filtration, (3) grinding plus churning, and (4) pressure filtration. Egg-processing methods which include some means of filtration are preferable to other methods, since the removal of all shell particles, membranes, and other materials can best be accomplished through filtration.

Breaking and canning operations are carried out as a continuous process. As pails of broken-out eggs arrive from the breaking tables, they are poured together in mixing tanks and processed by one of the methods mentioned. When anticoagulants are employed they are usually added to the yolk batter as it is mixed.

Frozen-egg products are usually packed in 30-pound cans (fig. 27). Special orders are sometimes packed in 5- or 15-pound cans. Prepared liquid-egg batter is weighed directly into the cans. As freezing causes expansion or "humping" of the batter, cans are filled only to within 2 to 3 inches of the top, thus providing space for expansion. After the liquid is frozen, enough additional batter may be added to fill each can and the can is returned to the freezer. This practice results in full cans with level surfaces.

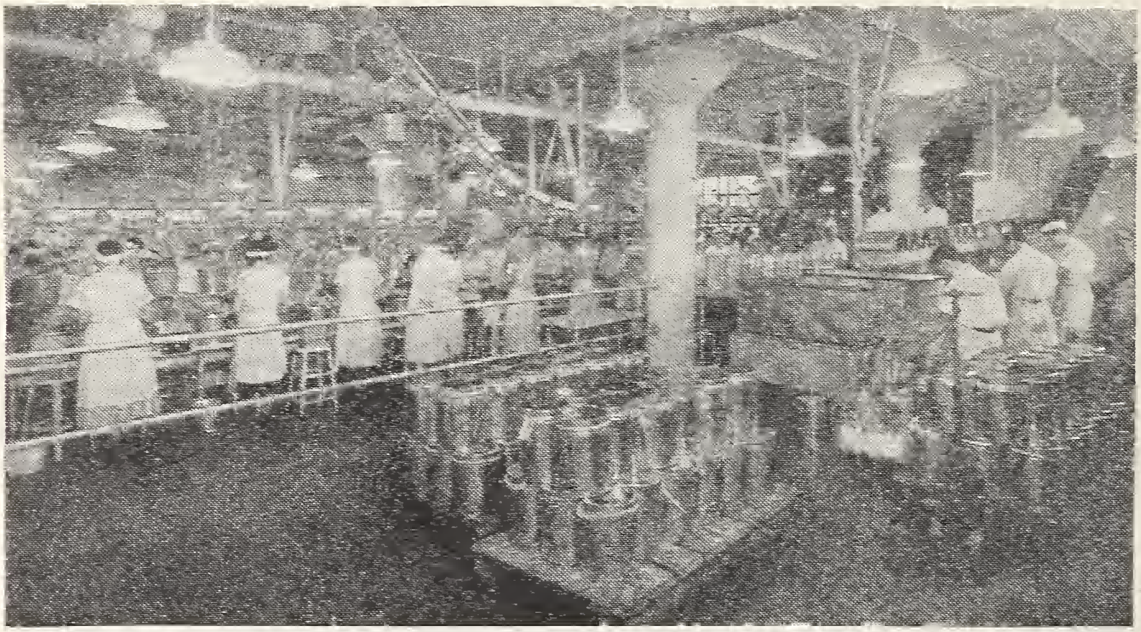

FIGURE 27.—Cans filled with broken-out eggs, ready to be sent to the freezing chamber.

Cans of batter are covered and taken from the processing department to the freezer on flat-topped hand trucks holding 24 to 30 cans. To insure a high-quality product, it is essential that freezing take place as rapidly as possible to retard bacterial development and subsequent decomposition and to prevent coagulation or separation of water from the yolk. Rapidity of freezing depends on spacing of containers and on temperatures used.

In commercial practice, egg batter is generally frozen at temperatures of −10° to −15° F. A period of 60 to 72 hours is required for the complete freezing of 30-pound cans of this batter at these temperatures. Rapid freezing is best accomplished by stacking cans of batter in a pyramid arrangement in the sharp-freezer, thus facilitating proper air circulation around each can (fig. 28). Free air circulation is essential for solid and uniform freezing. It is inadvisable to stack more than 20 or 30 cans in each pyramid. The cans of frozen eggs should be removed from the sharp-freezer at the end of the freezing period; otherwise, excessive pressure of the frozen material may burst can seams. Frozen-egg stocks are commonly stored in milder freezers maintained within the temperature range of 0° to −5°. Cans are placed on top of one another in large separate stacks, while awaiting shipment.

A quick-freezing process for the preparation of frozen-egg products has been developed. It consists in freezing a homogeneous egg emulsion in a thin film in a few seconds by passing it over a mechanically chilled refrigerated roll. This frozen material is then packed into cans which are immediately transferred to a sharp-freezer.

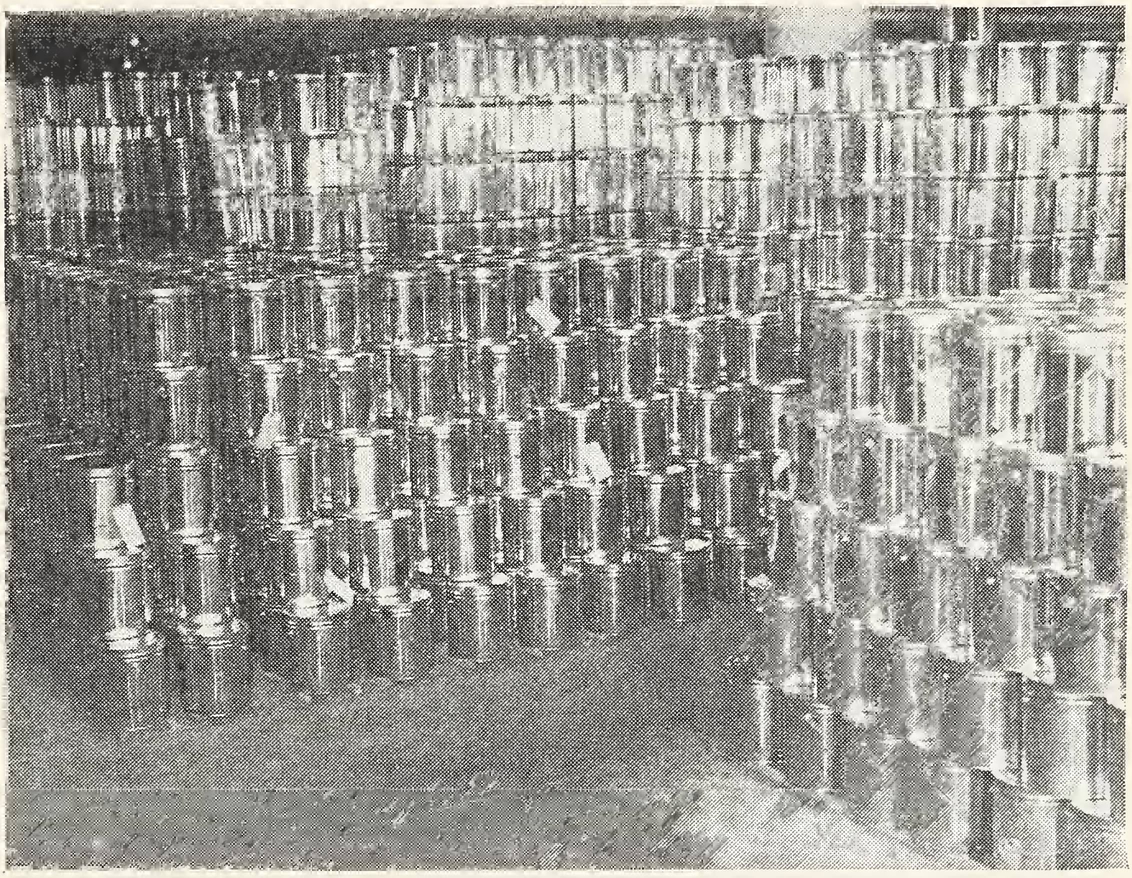

Figure 28.—Cans of eggs in freezing room of a breaking plant. They are stacked in such a way that cold air may circulate about each can.

Commercial shipments of frozen eggs are made in well-insulated freight cars and motortrucks, refrigerated by means of crushed ice and salt, solid carbon dioxide, or by mechanical methods. Shipping temperatures are maintained at 30° F., or lower; hence the product remains in a solidly frozen condition during shipment.

Importance of Sanitation

The paramount factor for the production of good-quality frozen eggs is proper sanitation. Ignorance or carelessness in the handling of frozen eggs causes serious losses. Any consideration of adequate sanitation must include proper construction, lighting, and ventilation of the plant, type of equipment, health and personal cleanliness of employees, and facilities for cleaning and sterilization of the plant and equipment. Of great importance, also, are rapid handling and low temperatures of eggs in the plant. The shortest possible time should elapse between the removal of shell stock from cold storage and the receipt of processed egg batter in the freezer. It is highly desirable also that temperatures unfavorable to the rapid multiplication of bacteria be maintained in the plant at all times. If batter is not subjected to warm temperatures and there is no delay in freezing, bacteria cannot multiply rapidly.

PLANT AND EQUIPMENT

Best results will be obtained if every department in the egg-breaking plant is housed in large well-ventilated rooms containing few pillars, ledges, pipes, shafts, and pulleys, which collect dirt. The walls and floors of candling rooms should be so constructed that they can be easily cleaned and will give maximum protection against temperature changes and dampness. If these features are disregarded, shell stock is subjected to additional contamination during candling. Furthermore, in candling rooms, good ventilation and maintaining temperatures at 50° to 65° F. are important. For the floors, walls, and ceilings of breaking, processing, and canning departments, the best material is tile or other impervious substance which will have a glossy finish after enameling. These departments should be well lighted and ventilated, and constant temperatures between 65° and 68° maintained.

Maximum cleanliness will be encouraged by enameling chairs, stools, and the framework of equipment a glossy white. Corrosion-resistant metal is desirable for the construction of table tops, trays, knives, separators, and other equipment coming in contact with egg batter. All equipment should be so designed as to eliminate cracks and crevices, thereby facilitating easy cleaning. Graniteware or glass cups are generally used in the breaking of eggs, because they afford a better background for inspecting the broken-out product. However, receptacles that chip easily are objectionable.

The floors, walls, and ledges require frequent cleaning to insure freedom of the plant from dust and grime. Table tops should be scrubbed and then treated with steam or chlorine solution daily or at more frequent intervals if necessary. Washing and steaming pails, tanks, and processing equipment at hourly intervals insure freedom from gummy egg deposits. It is advisable that trays, knives, separators, and cups be thoroughly cleaned and sterilized by steam at least every half hour, or after any contact with abnormal eggs. Frozen-egg cans should be thoroughly washed and steam-sterilized before use.

The bacteriological examination of all equipment at frequent and unannounced intervals affords an effcient means of preventing the introduction of large numbers of viable micro-organisms through dirty equipment. A well-equipped cleaning and sterilizing room of such capacity as will insure the prompt and thorough cleaning and sterilization of all equipment at all times is an important adjunct in a modern egg-breaking plant (fig. 29).

EMPLOYEES

A breaking plant preparing an uncontaminated product requires that its personnel have cleanly habits. Clean white caps and uniforms are worn by workers and changed daily or more frequently, if necessary. Adequate washbasins operated by foot-pedal controls and supplied with an abundance of hot water, liquid soap, and paper towels are generally provided in all departments of the plant. Persons leaving the rooms for any purpose are required to wash their hands thoroughly before resuming work. Strict sanitary precautions are insured by frequent inspections.

It is highly desirable that employees of egg-breaking plants be required to pass the rigid medical examinations required in many other food-processing industries. The perishable nature of frozen-egg products, together with the fact that great quantities of them may be incorporated in foods not sufficiently heated during their manufacture to insure the destruction of bacteria, indicates the desirability of such a procedure.

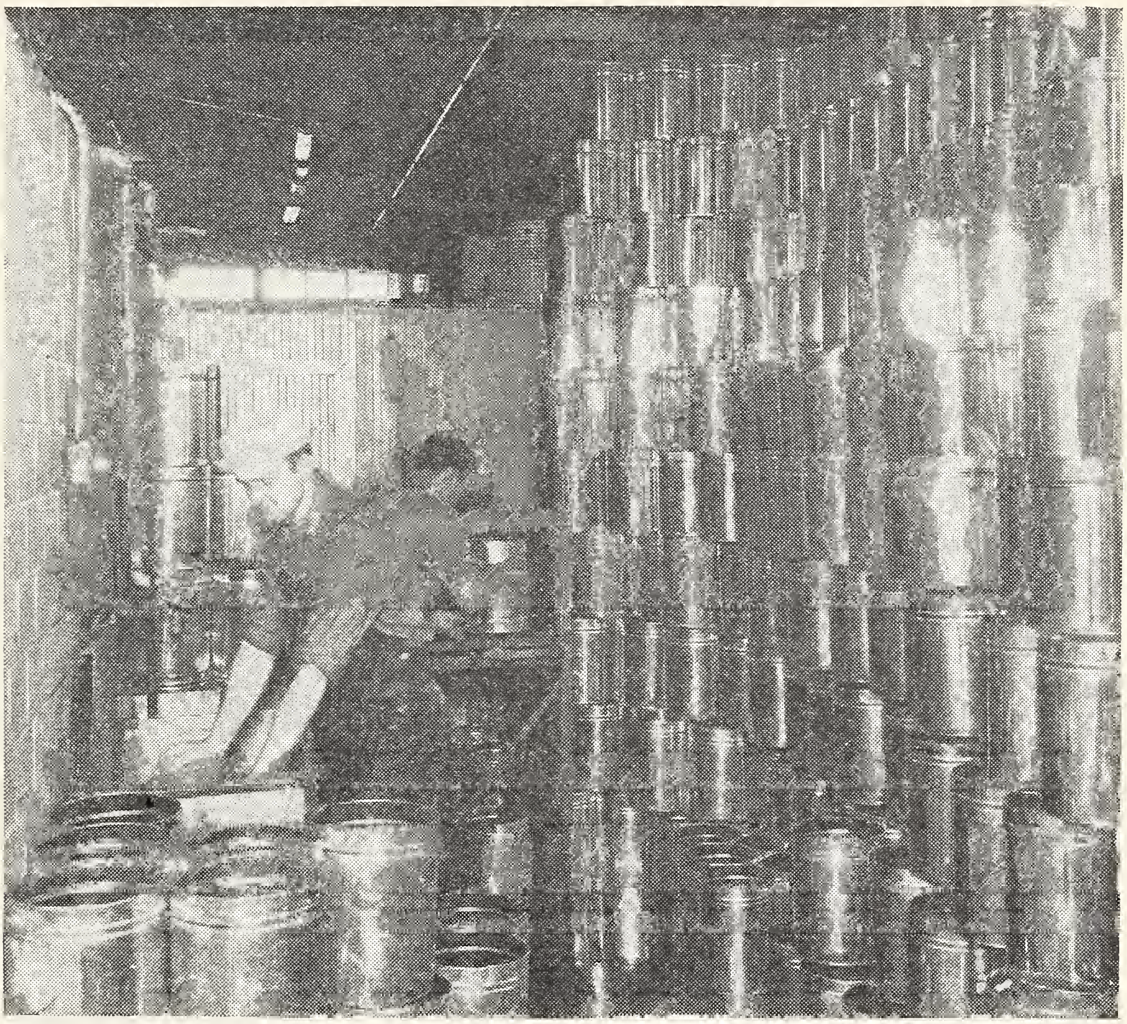

FIGURE 29.—Sterilization room. After being thoroughly washed, the cans are sterilized with live steam.

DRIED-EGG PRODUCTION[25]

The dried-egg industry is growing steadily, and the demand for dried-egg products has reached the point at which dealers now find it profitable to use high-grade current-receipt eggs for drying. The excellent quality of the dried products usually found on the market is largely responsible for their increased use by bakers and other consumers.

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[25] By T. L. Swenson, senior chemist, Food Research Division, Bureau of Agricultural Chemistry and Engineering.

Eggs normally contain approximately 73 percent of water. During the drying process about nine-tenths of the water is driven off, and the eggs are reduced to approximately one-fourth of their original weight. It requires 36 to 40 average-sized eggs to make 1 pound of dried material, which represents three times the monetary value of a dozen eggs in the shell. About 3½ pounds of liquid whole egg, 2¼ pounds of yolk, or 7½ pounds of white is required to produce 1 pound of each in the dried state.

Methods of Drying Eggs[26]

Three general methods—the spray, tray, and belt methods—are used by the trade in drying eggs, though each manufacturer may vary the procedure slightly according to his particular desire and experience.

By the spray method, the liquid egg is pressure-sprayed into the upper part of a high-ceiling chamber heated to a temperature of 160° to 170° F. The fine spray dries readily and is collected from the lower part of the chamber (fig. 30). Whole egg and yolk are the two products best suited for spray drying; white alone is too viscous to spray easily.

By the tray method, the liquid egg is run into metal trays of any convenient size or shape, usually made of aluminum or some of its alloys. Other metals, such as iron, are to be avoided because of their tendency to discolor the product. The liquid egg, usually the liquefied white, may be poured directly onto the trays or pumped to them through flexible tubing fitted with hand-controlled nozzles which run from the tanks of liquid egg to the drying room. The trays are placed on shelves in specially constructed cabinets. Hot air is forced through the cabinet, entering on one side and escaping through appropriate ducts on the other.

It requires from 6 to 12 hours to make one drying at a temperature of 110° to 120° F. The dry material is removed from the pans, collected in convenient bins, and graded for market. Egg white is the principal product dried by this method, although egg yolk is sometimes dried in the same way.

By the belt method a thin film of liquid egg is allowed to flow onto an endless belt made usually of aluminum. This belt traverses a warm chamber through which circulates filtered air heated to about 140° F. The belt is of sufficient length that the egg film is dried in one revolution, after which it is automatically removed by means of a metal scraper and allowed to fall into drawers or bins. The first drying requires 1½ to 2 hours. The product is next spread on trays with wire-screen bottoms and further dried in a "finisher," which is a large cabinet kept at 100° to 110° F. It is kept in the finisher for 2 to 3 hours, after which it may be graded into flakes of various sizes or powdered to a uniform fineness. The finished product usually contains 3 to 8 percent of moisture.

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[26] For more complete information on the preparation and uses of dried eggs, see TERMOHLEN, W. D., WARREN, E. L., and WARREN, C. C. THE EGG-DRYING INDUSTRY IN THE UNITED STATES. U. S. Agr. Adjustment Admin. PSM–1, 80 pp., illus. 1938.

FORMS OF DRIED WHOLE EGG AND YOLK

Flake-dried whole egg is the product which is scraped from the belt or pan in flake form. It is an attractive yellow product and is usually reconstituted for use in the ratio of 1 ounce of dried flake to 3 ounces of water. When reconstituted, it should have the liquid consistency of a fresh egg. Powdered whole egg is usually made by the pressure-spray method. It is a finely divided substance and is reconstituted in about the same manner as the flake-dried egg.

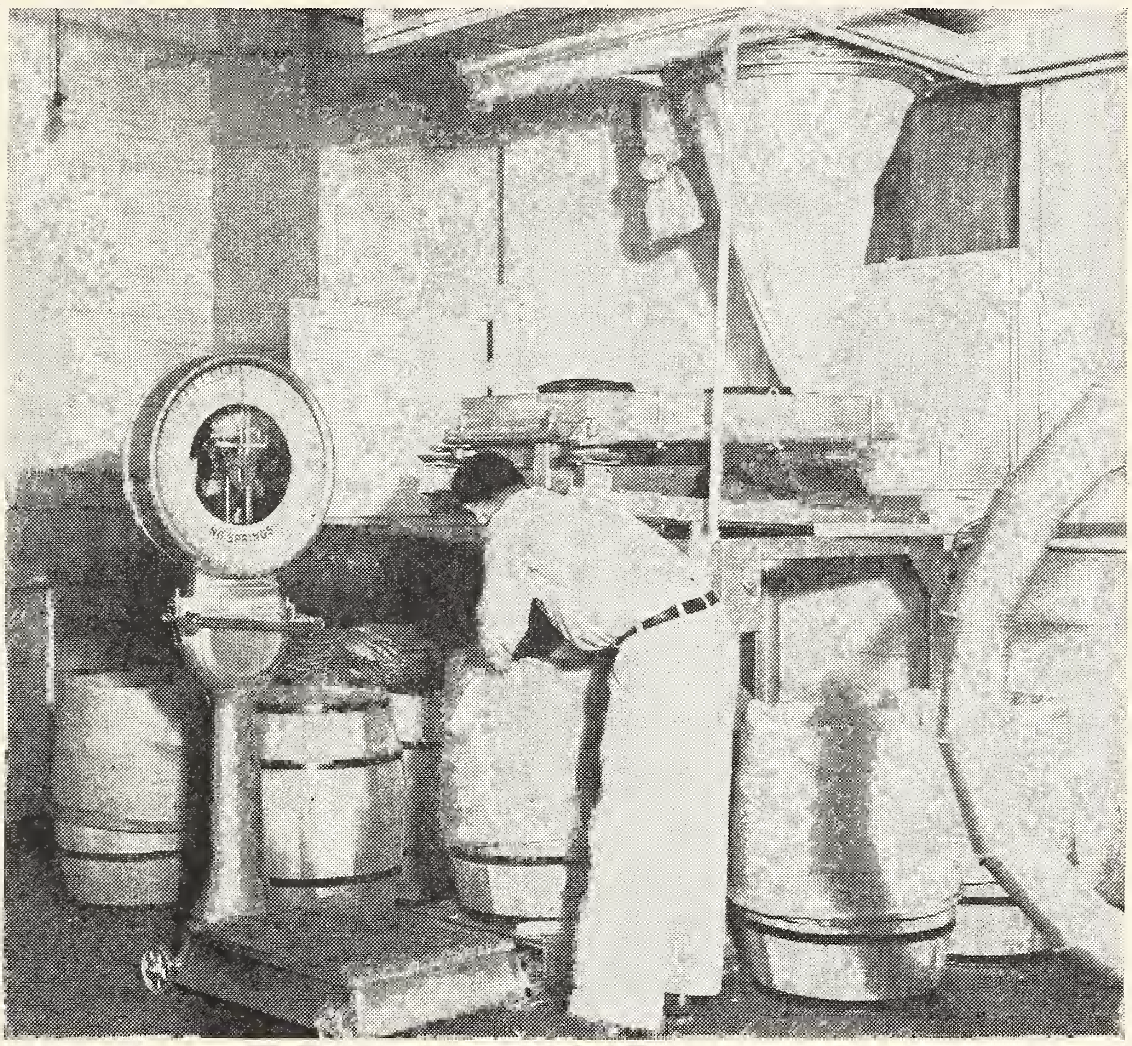

FIGURE 30.—Packing dried egg yolk in 200-pound barrels. The canvas funnel at the top of the picture is attached to the bottom of a large cyclone drying chamber on the floor above, into which liquid egg yolk is sprayed.

Flake-dried yolk is prepared on the belt or sometimes by the tray method. It is collected as flakes. Drying usually takes from 3 to 4 hours. It is reconstituted in the proportion of 1 ounce of dry yolk to 3 ounces of water. A characteristic liquid-yolk body should result. Powdered dry yolk is made by the pressure-spray method. It is a finely divided product. Importance of color in the dried material depends on its intended use. A rich yellow is usually desirable. Powdered dry yolk is reconstituted in the same proportions as flake-dried yolk.

Uses and Preparation of Dried White

The preparation of dried white is an important industry. The product finds its principal application in the food industries, but surprisingly large quantities go into other industries of varied character. It may be used as a sizing material, an emulsifying agent, an adhesive, and a body for pigments. The development of new industrial uses is to be expected in any connection requiring a soluble protein. Its chief competitor is blood albumen, a packing-house byproduct. Both the chemical make-up and the physical characteristics of dried white vary with the process of preparation and perhaps with the grade and variety of eggs used. In general, insufficient attention has been paid to the manufacture of dried white particularly suited to a given purpose, but it is evident that the requirements for a good product vary with its application. Consequently, no one process of manufacture can be held superior in all respects. For food purposes, however, the value of egg white should be based on its color, its ability to redisperse in water (reconstitute itself), its cleanliness, and the nearness with which its behavior in the hands of baker or candy maker approximates the behavior of the fresh undried white of egg.

Fresh egg white consists of two parts—a thick, jellylike fraction and a thin, comparatively mobile fraction. The two may be separated by a sieve. Industrial means for the preparation of dried white require not only a process for removing water but also one for liquefying the jellylike fraction. This thinning process is necessary because it is difficult to dry thick white adequately; and once dried, the protein remains insoluble in water, just as it was in the fresh state. Thinning is ordinarily accomplished by allowing the liquid whites to ferment in vats for several days at ordinary room temperature, or the vats may be kept in a heated room. As fermentation progresses a heavy, stringy, spongy foam forms over the tops of the vats. The foam may be collected and reclaimed, as described later. The liquid white under the foam develops a watery consistency. It has an odor comparable to that of alfalfa hay, a slightly salty taste, and a slightly acid reaction. The acidity is usually neutralized with ammonium hydroxide before the thinned white goes to the drier. Drying usually requires 6 to 16 hours, depending on temperature and air control in the equipment. This fermentation is a natural process usually accompanied by a bacterial break-down of the carbohydrates of the white. Dried fermented white contains approximately 0.5 percent of sugar as compared with about 0.4 percent in fresh white.

Fermented egg white is usually flake-dried. It is not a true crystalline substance, but because of its sparkle and sheen, together with its irregular shape, it is usually referred to in the trade as crystalline albumen. This product is ordinarily reconstituted in the ratio of 1 ounce of albumen to 12 ounces of water; however, these proportions may vary, according to the needs of the consumer.

For certain uses, a powdered albumen is preferred. This is usually made by grinding the flake or crystalline albumen in a suitable mill and screening it.

In order to obtain a uniform dried product of unfermented albumen in the flake or crystalline form, the thick fraction of egg white must be liquefied. Mechanical pumping and straining or screening is used to some extent, and acid hydrolysis may be combined with pumping and straining. Methods used by the trade are covered by private patents. Increasing quantities of whites are being dried by spray methods from whites liquefied by acids or enzymes.

The Food Research Division of the Bureau of Agricultural Chemistry and Engineering has developed a rapid method for thinning egg whites by controlled enzymatic action.[27] It was found that the addition of a suitable protein-digesting enzyme accomplished this result. The most suitable one, however, is trypsin, because the natural alkalinity of the white is favorable to the action of this enzyme but deterrent to that of other protein-digesting enzymes.

It is, therefore, possible to regulate the time required for thinning the egg white by regulating the dosage of trypsin and the temperature at which the enzyme is allowed to act. Judging from observations on eggs held in cold storage, the activity of the enzyme is retarded by low temperature but it by no means ceases. The growth of bacteria in the white appears to be retarded far more. As a consequence, at temperatures of 39° to 43° F. an almost sterile, thin albumen can be prepared, provided sufficient time is allowed for the action of the enzyme.

The product made by drying the enzymically hydrolyzed egg white has been tested thus far only in relation to its use in foods. The standard whipping and baking tests were employed. The whipping test already has been discussed in the section on eggs in the manufacture of food products. In the baking test, angel-food cakes made with the white to be tested were compared as to texture, flavor, and volume with cakes made according to the same formula but with commercial fermented white. According to these tests, the enzymically prepared white behaves equally as well as the dried fermented white of the trade.

This new method for the preparation of dried egg white needs further development, but even as now used, the high sugar content of the product, its freedom from micro-organisms, and in general its closer resemblance to fresh white more than offset difficulties not yet overcome. The enzyme-treated product can be prepared much more rapidly, with a substantial saving of time to the factory, and that the process of preparation can be controlled by the operators to a degree impossible with the usual fermentation processes.

PROCESS OF RECOVERING FOAM FOR DRYING

In addition to the method described for enzymic liquefaction of egg white, the Food Research Division has devised a method for the recovery of the foam which forms over the tops of the vats of naturally fermenting egg white.[28] This fermentation is greatly accelerated in a warm room, but under such conditions the foam that collects is a heavy, spongy, stringy mass which does not become thin on continued standing, even when separated from the liquid white. It has been found that this stringy foam can also be converted to thin albumen. In this process, it is acidified with 20-percent citric acid by adding 1 part of acid to 45 parts of foam and stirring well. A solution of pepsin in a small quantity of citric acid is then added to the acidified foam in the ratio of 1 part of enzyme to approximately 10,000 parts of foam. In plant operation, to 50 gallons of foam there should be added 2 quarts of 20-percent citric acid and 5 grams of pepsin. The mass should be stirred occasionally until liquefaction is complete. Usually 4 to 5 hours are required. The liquefied foam is then neutralized and dried. The quality of this product compares favorably with that of the usual commercial dried egg white.

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[27] Covered by U. S. Patents Nos. 2,054,213, issued Sept. 15, 1936, 2,062,387, issued Dec. 1, 1936, and 2,073,411, issued Mar. 9, 1937. These are public-service patents dedicated to the free use of the public.

[28] This method is covered by U. S. Patent No. 2,110,613, issued Mar. 8, 1938. This also is a public-service patent.

OIL TREATMENT OF SHELL EGGS[29]

Changes Occurring in Shell Eggs During Storage

Of the internal changes that take place during the commercial holding of shell eggs in cold storage some are physical, some chemical, some both physical and chemical. Among the most important changes are the following:

The air space increases in size because of loss of moisture by evaporation; the weight decreases; the white tends to become thin; owing to the continued loss of carbon dioxide, the white becomes alkaline (in some cases the change is great, and the hydrogen-ion concentration changes from pH 7.6 to pH 9.5 or 9.7); the white also develops a yellowish tinge after a time; the yolk membrane weakens and the yolk flattens when broken out.

With the exception of the loss of moisture and weight, these changes are biochemical and, in a measure, are stimulated by enzymes normally present in eggs. An enzyme is an organic catalyst elaborated by a living cell. Under certain definite conditions it causes specific chemical reactions and physiological changes. The enzyme itself is not spent or used up during the reaction, and it continues its activity as long as suitable conditions exist. Maximum enzyme activity is subject to certain limitations of temperature and to the degree of hydrogen-ion concentration. Therefore, the importance of maintaining a hydrogen-ion level considerably below the optimum one for the enzyme becomes apparent. In the formulation of any method for preserving the quality of eggs, consideration should be given to the stabilizing of the hydrogen-ion concentration, which should remain about the same as that of fresh eggs.

Carbon dioxide has been used to stabilize the hydrogen-ion concentration of eggs, and as long as they are held in an atmosphere containing effective amounts of carbon dioxide, the hydrogen-ion level remains fairly constant. Introduction of carbon dioxide into cold-storage rooms has already been mentioned in this circular. Removing eggs from this special atmosphere lowers their quality rather rapidly. From this discussion it is seen that a method for controlling hydrogen-ion concentration is needed which will be effective throughout the entire channel of trade.

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[29] By T. L. Swenson (see footnote 25, p. 69).

Purpose and Methods of Oil Treatment

Dipping eggs for a short time in a suitable oil partially seals the pores in the shells. As a result it slows down the rate of loss of carbon dioxide, retards the loss of moisture, and tends to retard or inhibit changes in eggs.

Extensive investigations of egg-oiling methods, conducted by the Food Research Division of the Bureau of Agricultural Chemistry and Engineering, have broadened the general knowledge of the oil treatment of shell eggs. This in turn has stimulated further industrial research toward the development of inert mineral oils or emulsions suitable for use as vehicles in protective treatment. Paraffin oils are commonly used although some oils of asphalt base have proved satisfactory. The proper physical constants (specific gravity, viscosity, and pour point) are more important than the quantity of oil applied.

Three general methods are used in oiling eggs, as follows: (1) Open dipping. Eggs are carried on special racks which move on an endless conveyor. Each rack, holding 3 dozen eggs, is carried through an oil chamber, the process being that of simple immersion. (2) Spray process. This method sprays the oil over the eggs as they pass through an oil-spray chamber. A conveyor type of machine is used. The spray and open dipping processes are extensively employed in the industry. (3) Vacuum-carbon dioxide method.

VACUUM-CARBON DIOXIDE METHOD[30]

By this method, developed by the Food Research Division, the eggs are placed in a chamber the lower part of which is an oil well containing a considerable quantity of a good grade of paraffin oil (fig. 31). The chamber is closed and the eggs are submerged in the oil. A partial vacuum of slightly more than half of ordinary atmospheric pressure is then drawn on the chamber through the medium of an auxiliary vacuum tank. When the desired vacuum is attained, the eggs are raised above the surface of the oil and the vacuum is suddenly released by admitting carbon dioxide instead of air into the chamber. The entire eggshell is covered with a film of oil and the pressure within the egg is less than that outside the shell. Since it is natural for pressure to equalize on both sides of a membrane or permeable wall, the oil is carried into the pores of the shell as equilibrium between internal and external pressure is reached.

Oil is drawn into all the shell pores, but the vacuum used is not sufficient to rupture the membrane inside the shell. Tests show that nearly four times as much oil is deposited in the shell pores as under dipping and spraying processes and that the shell holds the oil better, resulting in a more effective and lasting seal. It has also been demonstrated that the effect of oiling on the breaking strength of eggshells is so slight that it may be disregarded.

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[30] Covered by U. S. Patent No. 1,888,415, a public-service patent dedicated to the free use of the public.

Oiling by the vacuum-carbon dioxide process appears to be especially efficient in reducing the loss of carbon dioxide (one of the causes of watery whites) from eggs. Owing, perhaps, to rapid absorption by the shell pores under vacuum, less oil adheres to the surface than on eggs dipped under ordinary atmospheric pressure, and flats and fillers are stained to a less degree by surplus oil. The oil is scarcely noticeable on the shells, and white and brown shells take the oil equally well.

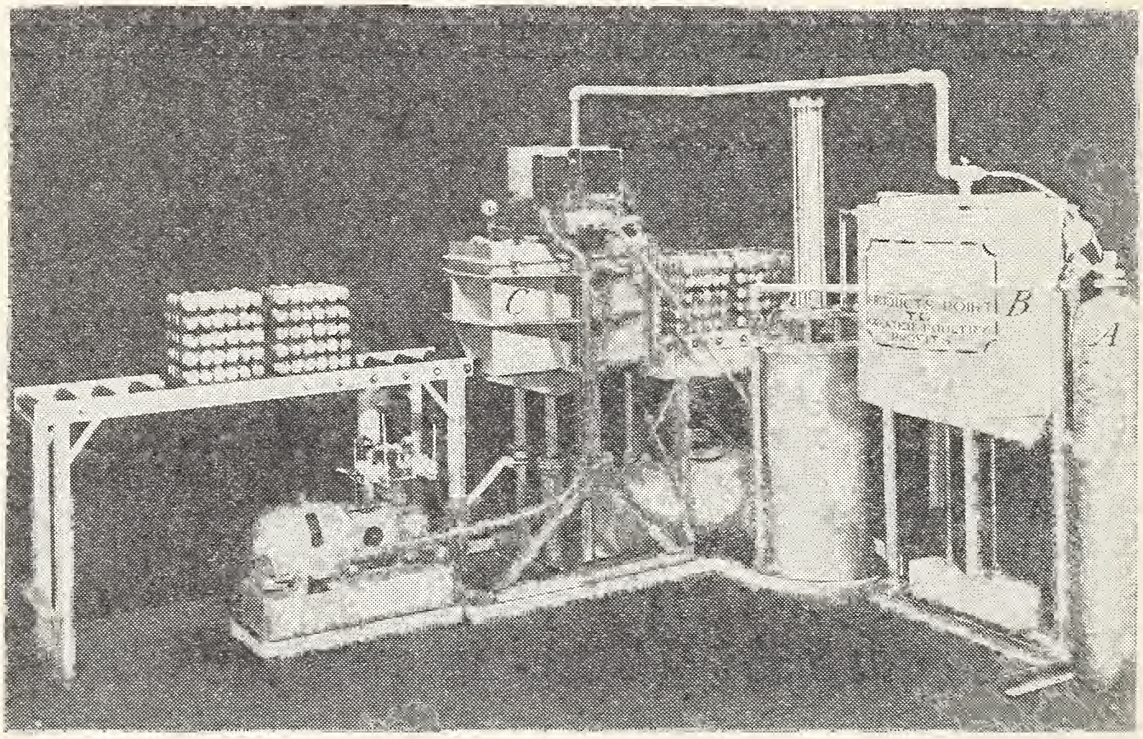

Figure 31.—Apparatus for treating eggs by vacuum-carbon dioxide method to improve keeping: *A*, Carbon dioxide chamber; *B* auxiliary vacuum tank; *C*, vacuum oiling chamber (closed).

The three oiling methods have proved beneficial in retarding the changes in quality which occur gradually during storage. The beneficial effects of the sealing are carried through to the consumer. The cost of vacuum treatment is slightly higher than that for dipping.

The vacuum method has been found to have a quality-preservative coefficient ranging from 25 to 35 percent higher than ordinary oiling methods. Oiling makes good eggs keep longer; it also makes them keep better. Observations indicate that with vacuum-carbon dioxide treatment a greater percentage of the eggs come out of normal storage without loss of grade.

Fire-protection methods and auxiliary equipment in buildings where this process is being used depend on fire hazards existing in the building. Carbon dioxide is used as a fire extinguisher, but paraffin oil is flammable. A survey of the building for fire hazards should be made before the process is begun.

Oiling Eggs Before Shipment

The Division's experiments show that the use of oils of low viscosity and low pour point is feasible. Successful use of unheated light oils indicates the possible advantages of oiling the eggs on farms where they are produced, especially in very dry climates where water loss and consequent deterioration are rapid.

Certain precautions are necessary in oiling. The eggs must be clean and dry and must be cooled for several hours—long enough to allow the heat to be dissipated—otherwise, the whites tend to become cloudy in storage. If eggs are oiled as soon as they are candled, the chances are that most of the good quality will be maintained. It is a distinct advantage to have the oiling done before transportation, which affects subsequent keeping quality adversely. Untreated eggs, particularly those in the higher grades, transported long distances and then stored, undergo heavy losses. Eggs vacuum-dipped and then transported for long distances and stored for normal periods have shown remarkable ability to retain their good quality, a surprisingly large proportion of them making top grades. Eggs washed in lye water of proper strength (see p. 12), then promptly oiled by the vacuum-carbon dioxide method, and shipped and stored have also shown unusual keeping qualities.

EGG QUALITY AS INFLUENCED BY BREEDING AND FEEDING [31]

Effect of Breeding

Until recently the quality of eggs was believed to be controlled almost entirely by the diet of the layer and the care given to eggs after they were produced. Research work, however, has shown that some important characteristics governing the commercial grade of eggs are hereditary. Some of these characteristics are egg weight, proportions of thick and thin albumen (fig. 32), deterioration of egg white, and loss of moisture.

It has been demonstrated at the Beltsville Research Center, Beltsville, Md., that egg weight can be improved by proper breeding methods (fig. 33, *A*). In one strain of Single-Comb White Leghorns, from which the results shown in figure 33, *A* were obtained, the average annual egg weight was gradually increased from 23.2 ounces per dozen in 1934 to 24.8 ounces in 1938.

During the period that the egg weight was being increased in the White Leghorn flock, it was observed that standard weight was reached earlier each succeeding year. In 1934–35, when the average annual egg weight was only 23.2 ounces, the Leghorns failed to produce in any month eggs that averaged 24 ounces per dozen. In 1935–36, when the average annual weight was 23.6 ounces per dozen, the eggs averaged 24 ounces per dozen in March. In 1936–37, the average annual weight was 24 ounces and the standard weight of 24 ounces was reached in February. In 1937–38, the average annual weight was 24.8 ounces per dozen and they attained a weight of 24.3 ounces per dozen in January. In 1938–39, the average annual weight was 25.2 ounces per dozen, and a weight of 24.6 ounces was reached in December, or 4 months earlier than in 1935–36. Reducing the time required for pullets to lay eggs of standard weight is equally important, from a commercial standpoint, as improving the average annual weight of eggs.

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[31] Section on breeding by Berley Winton, senior poultry husbandman, Animal Husbandry Division, Bureau of Animal Industry; section on feeding by Harry W. Titus, senior biological chemist, Animal Nutrition Division, Bureau of Animal Industry.

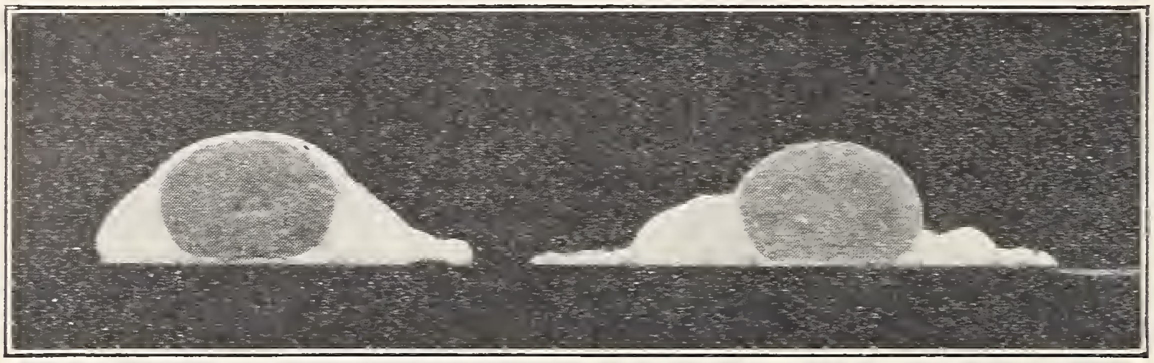

FIGURE 32.—Two poached eggs in cross section showing relative thickness, evenness of distribution, and quantity for the two types. The egg at the left is from a line of chickens bred for a large percentage of thick albumen: the one at the right is from a line of the same breed, bred for a small percentage.

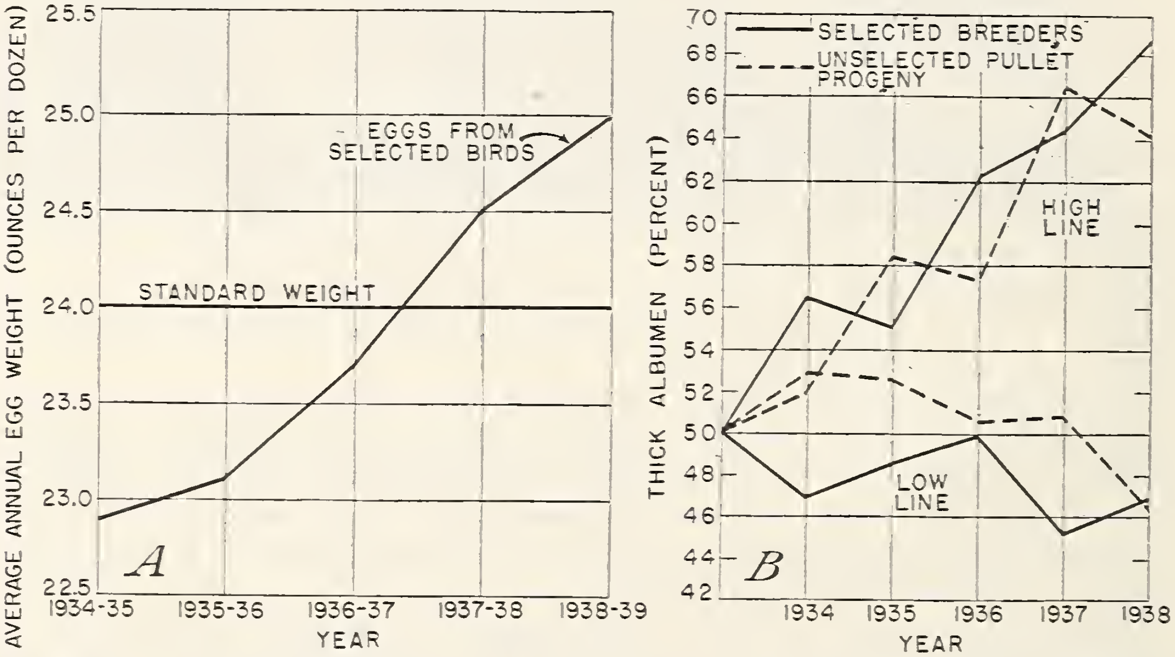

FIGURE 33.—Experiments show: *A*. A progressive increase from year to year in weight of eggs from selected birds: *B*. that progeny of selected birds produce more thick albumen than the progeny of unselected birds.

The percentage of thick albumen is an individual and hereditary characteristic. Data obtained indicate that by proper selection a strain of chickens can be developed that will lay eggs having a high percentage of thick white. This fact is shown in figure 33, *B*, which gives results obtained from two strains of Rhode Island Reds. In 5 years' time one strain has been developed that laid eggs containing

68 percent of thick albumen. This is high in comparison with an average of only 45 percent of thick albumen from the other strain. The parental stock of both strains was the same and produced eggs containing an average of about 50 percent of thick albumen.

Another factor that appears to be hereditary is the rate of deterioration of the thick white. Although there was no significant difference when fresh, the eggs produced by different lines of White Leghorns differed materially after they were held. Fresh eggs from two lines had exactly the same percentage of thick white, but after these eggs had been held at approximately 78° F. for 21 days under the same environmental conditions, the percentage of thick white for those in one line was 32 percent and for those in the other line 13 percent. This work indicated that the rate of deterioration of thick white depends on heredity factors as well as on conditions under which the eggs are kept.

Two definite lines of White Leghorns differing in the hereditary trait of loss of moisture from eggs have been established at the Beltsville Research Center. Eggs produced by one of the two lines had an average moisture loss of 9.2 percent, and those of the other line, 6.6 percent, for the first 14 days of the incubation period.

NATIONAL POULTRY IMPROVEMENT PLAN

The results obtained in breeding for improvement in interior and exterior quality of eggs have caused some of the foremost poultry breeders in the United States to initiate a program of selecting breeding stock not only for numbers of eggs but also for the quality of eggs produced. This viewpoint largely accounts for the active interest displayed by poultrymen and scientific investigators in the selection of breeding birds on the basis of trap-nest records, pedigree, and the progeny test. A widespread desire to build up a more efficient poultry enterprise by producing healthier chickens and better eggs, and to establish the industry on a sounder economic basis, crystallized in 1935 in the creation of the National Poultry Improvement Plan. Authoritative identification is given high-production breeding stock, hatching eggs, and chicks; pullorum disease is fought; and more efficient methods of breeding are encouraged. In 1940, 44 States participated in the plan. Supervision, inspection, and certification are provided by official State agencies in cooperation with the Federal Bureau of Animal Industry (fig. 34).

The viability of poultry is highly important to owners. Special experimentation to improve viability is under way at the Regional Poultry Research Laboratory established in 1938 at East Lansing, Mich.

Influence of Feeds

A chicken in full production uses 30 to 40 percent of her feed for making eggs, but if she produces only about one egg per week, she uses only 6 to 8 percent of her feed for this purpose. In general, the chicken's maintenance requirement—or at least a large part of it—must be met before feed can be used for egg production. Therefore, the more feed a chicken consumes above her maintenance requirement, the more material she has for making eggs. Nevertheless, there are times, especially in the spring, when hens as well as pullets will lay a few eggs even if they receive so little feed that they are unable to maintain their live weight.

If a high level of feed consumption is to be maintained, the diet must be carefully balanced so that it supplies adequate but not excessive quantities of protein, minerals, vitamins, fat, and carbohydrates. The usual ingredients of a well-balanced diet for laying chickens consist of one or more of the cereal grains; cereal byproducts, such as wheat bran, wheat middlings, and corn gluten feed; protein supplements, such as meat scrap, fish meal, dried skim milk, dried buttermilk, soybean meal, and corn gluten meal; sources of minerals, such as limestone, oystershell, and salt; and vitamin supplements, such as cod-liver oil and alfalfa-leaf meal. Detailed information on the feeding of chickens may be obtained from one's State college or from the United States Department of Agriculture, Washington, D. C.

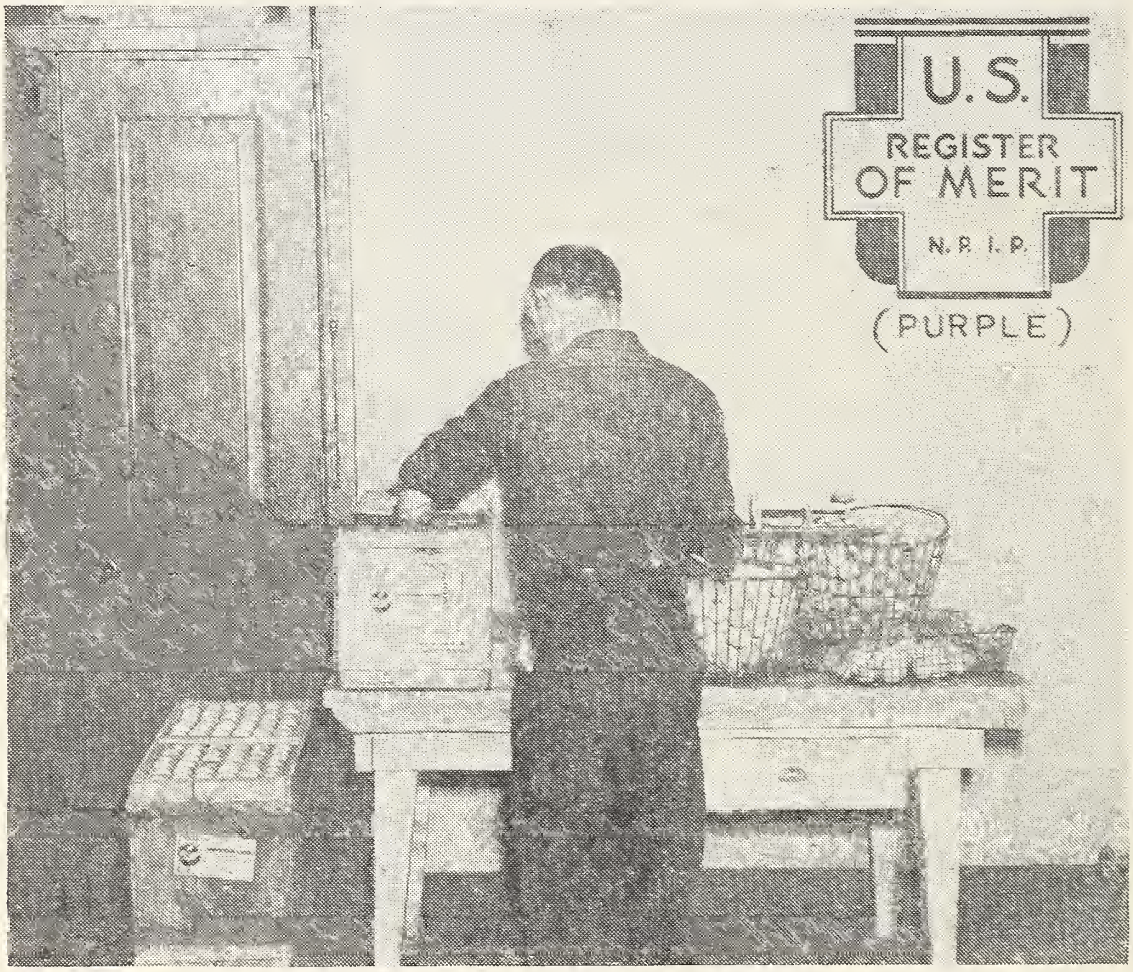

FIGURE 34.—Selecting hatching eggs laid by flock developed under the National Poultry Improvement Plan. Note labels on specially packed cases. Design at top of picture is one of several used to identify progressive breeding stages of flock.

If chickens are fed diets of rather low protein content, a high rate of egg production cannot be maintained and the eggs that are produced tend to be small. To obtain maximum egg production the diet should contain about 16 percent of protein and about 20 percent of this protein should be derived from animal sources, such as dried skim milk, dried buttermilk, fish meal, and meat scrap. In general, if the diet contains some dried skim milk or dried buttermilk the eggs tend to be slightly larger than if these feedstuffs are not used.

The vitamin content of eggs may be affected by both diet and management. The content of vitamins A, B_1, G, and D in the egg can be increased by feeding diets that contain relatively large quantities of these vitamins. The better sources of vitamin A are cod-liver oil, certain other fish oils, alfalfa-leaf meal, alfalfa meal, and yellow corn. One of the best sources of vitamin B_1 is dried yeast. Other good sources are the oil-seed meals and the byproducts of the milling of wheat for flour. The cereal grains are also good sources of this vitamin. The better sources of vitamin G are dried whey, dried buttermilk, dried skim milk, alfalfa-leaf meal, fish meal and the better grades of meat scrap. For increasing the vitamin D content of eggs, cod-liver oil, sardine oil, and certain other fish oils may be used. However, during the spring, summer, and autumn, chickens on range generally get a good supply of vitamin D from sunshine. The vitamin D content of the eggs of such chickens tends to increase appreciably from March to June but may decrease during the warmer months of the year because of the tendency of the chickens to seek shade when the weather is hot.

Should light-colored yolks be desired, the chickens should be confined in laying houses or in bare yards and fed a diet that contains little or no yellow corn and but little alfalfa meal or alfalfa-leaf meal. The richer shades of yellow may be obtained by feeding diets that contain as much yellow corn as possible and from 5 to 10 percent of alfalfa products. Deep orange-red yolks may be obtained by feeding 0.5 to 2.0 percent of ground pimiento pepper or chili pepper. Fresh green feed also tends to increase the color of the yolks; however, an excessive intake of green feed may cause the yolks to acquire an undesirable green-yellow or a red-yellow color.

It is best not to permit laying chickens to eat certain feedstuffs and plants. For example, if there is more than 5 percent of cottonseed meal in the diet, the yolks tend to become mottled if the eggs are stored for several months; also the whites may acquire a pink tinge. Certain plants, such as cheese weed, have a similar effect on the white. Shepherds-purse and field pennycress have been reported to produce a green color in both the white and the yolk. Many strongly flavored feedstuffs, such as turnips, onions, garlic, and leeks, sometimes produce undesirable flavors in eggs, especially if large quantities are consumed. Certain fish oils have also been found to produce a fishy flavor, but cod-liver oil or sardine oil of good quality ordinarily have no undesirable effect on the flavor of eggs, if fed at the proper levels.

USES OF INEDIBLE EGGS[32]

A part but by no means all of the eggs that have lost their value for food go into industrial products. Printing, textile, and chemical plants use considerable quantities of them. Spoiled eggs, however, are a heavy loss to the poultry industry even though their value is a small fraction of that of edible eggs.

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[32] By R. W. Frey, senior chemist, and L. S. Stuart, associate bacteriologist, Industrial Farm Products Research Division, Bureau of Agricultural Chemistry and Engineering.

Tanner's Egg Yolk

Tanner's egg yolk is one of the important inedible-egg products. In the United States the term "tanner's egg yolk" usually refers to a product made with the whole egg, not including the shell, and does not comprise, as the name implies, the yolk only. The term, however, may be used loosely at times to mean a product made from imperfectly separated yolks and whites as well, or one consisting of yolks completely freed from the whites.

Tanner's egg yolk is made from those eggs, of both the hen and duck, that are unfit for human consumption but do not have a repulsive odor. The principal sources of these eggs are the "rejects" from dealers and cold-storage holdings and the infertile eggs of hatcheries. These include eggs graded as white rots, blood rings, green whites, moldy shells, stuck yolks, sour eggs, and eggs with an abnormal odor. Checks, cracks, and leakers of edible grade may be included at times, and also good eggs when bad ones have been broken with them.

Liquid tanner's egg yolk is made simply by thorough mixing of the whole deshelled egg with a suitable preservative. This must be done promptly after the eggs are broken out of the shell, in order to avoid decomposition and material loss of emulsifying properties.

SALTED AND SALT-FREE YOLK

In the trade there are two broad types of liquid tanner's egg yolk, defined by the methods used for preservation. These are known as salted egg yolk and saltless, or salt-free, egg yolk. For many years practically all liquid tanner's egg yolk was of the first type, being preserved with common salt. The quantity of salt used for this purpose varies from one-sixth to one-fourth of the weight of the deshelled eggs. Probably the most extensively used proportions are 20 pounds of salt to 100 pounds of eggs.

Producers of chrome-tanned leather who desire to blend egg yolk with natural oils for the fat-liquoring, or incorporation of oils, in leather often demand a yolk product without a high salt and ash content. Large quantities of salt in the egg yolk reduce the stability, or permanence, of the oil emulsions.

Egg yolk of the so-called salt-free type is kept from spoiling by the use of preservatives more powerful than salt. In preparing the salt-free yolk, the preservative is dissolved and added in quantity of water equivalent to the weight of salt used for the salted yolk. Therefore, a given weight of either type contains the same quantity of egg. This procedure has been followed for convenience in adjusting price and in using these products.

The quantity of salt necessary for preservation may be reduced materially by adding small quantities of borax, boric acid, sodium benzoate, or sodium fluoride. Another method of preservation consists in rendering the yolk strongly acid with lactic or phosphoric acid and then adding 5 to 6 percent of salt. The acid in the yolk must be neutralized prior to use. Desiccation is also employed.

Within the last few years tanners have been demanding that egg yolk comply with certain requirements. As a rule, liquid salted egg yolk must be guaranteed to contain not less than 9 percent of oil and not more than 16 to 18 percent of salt. Salt-free yolk must contain not less than 10 percent of oil.

A manufacturers' estimate places the total annual production of tanner's egg yolk in the United States at 10,000 to 12,000 barrels, or 5,500,000 to 6,500,000 pounds per year.

Shipments consisting in whole or in part of inedible or spoiled eggs are classified under the terms of the Federal Food, Drug, and Cosmetic Act as adulterated eggs. Interstate shipments of tanner's egg yolk or similar products made from inedible eggs are required by law to be denatured in such a way that they cannot be used for food purposes.

DRESSING FOR LEATHERS AND FURS

Because of its excellent emulsifying power, tanner's egg yolk is one of the most effective materials used in fat-liquoring, a method employed for incorporating oils and fats by drumming the leather in an emulsion of oil in water. This is especially true in the making of suede and white leathers and to a lesser degree for other leathers, such as grain-finished calf leather. Large quantities of egg yolk are also incorporated directly into tanning formulas.

In the dressing of fur skins, egg yolk finds a somewhat similar application. It is sometimes rubbed directly into the flesh side of the tanned skin, being used either alone or with mixtures of oils.

Industrial Egg Albumen

Egg albumen is used for seasoning in finishing certain types of leather, particularly glazed colored stock. The advantage of egg albumen over blood albumin is its freedom from color and iron. The albumen fixes the dyestuffs used, to a certain extent, and from the heat of drying and glazing it is coagulated, thus producing on the surface of the leather a more or less insoluble film. It is used also to season gold-beater's skin, drum heads, and banjo heads, and as an adhesive for a variety of purposes, including the attaching of gold lettering and gold and silver leaf to leather.

Egg albumen is also a vehicle for ammonium or potassium dichromate in sensitizing zinc or aluminum plates for offset work, such as the printing of maps. It is used in the preparation of a substratum for collodion wet-plate negatives used in photography, as a constituent of some ivory substitutes, and for albumen colors in textile printing, in which the dye is mechanically held to the fiber by virtue of the coagulated albumen.

Feed and Fertilizer

In point of quantity, more spoiled eggs are used for hog feed and for fertilizer than for tanning and the arts. Certain kinds of rots and breaking-plant and incubator refuse are disposed of locally as feed for hogs. This material is rich in proteins and if decomposition has not progressed too far is readily eaten by the animals. It may be fed in mixtures with grain or other feeds. The quantities of eggs rejected in packing are usually insufficient to warrant their use in the manufacture of tankage.

USE OF EGGS AND CHICK EMBRYOS AS CULTURE MEDIA[33]

Many human and animal diseases are more easily fought as a consequence of the recent extensive use of eggs and chick embryos as media for the culture of viruses and the production of vaccines and serums of high potency employed in human and veterinary medicine. The cost of preventing "sleeping sickness" of horses, for example, was greatly reduced by the discovery that virus could be developed in inexpensive embryo chicks instead of in the brain tissue of horses (fig. 35).

Incubated eggs in which the embryos had reached varying stages of development were among the first materials used in primary studies of the structure and growth of embryos in general. Observations made in connection with chick embryos established basic information for the study of many problems, not only in embryology, but in genetics, histology, and pathology as well.

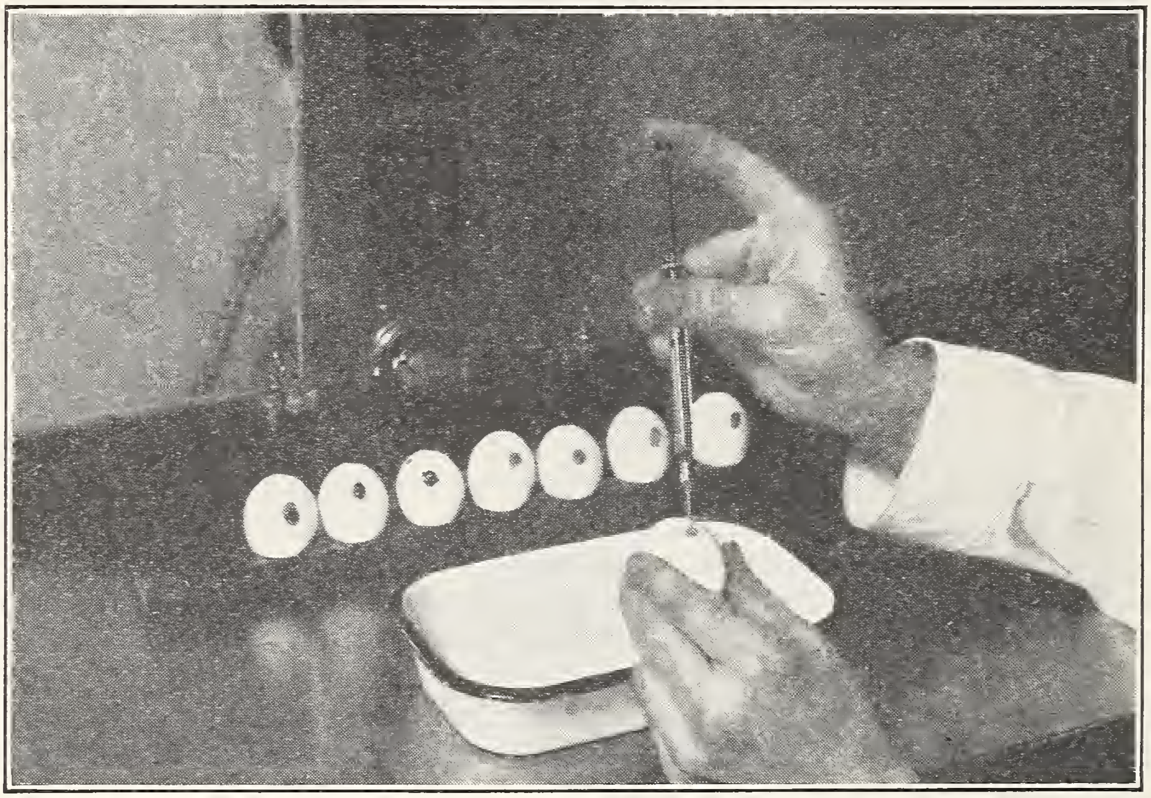

Figure 35.—Inoculation of chick embryos in a study of virus diseases. A small hole is drilled through the shell to admit the syringe needle, after which the hole is sealed with wax.

In the investigations of infectious animal diseases, the isolation and cultivation in a pure state of the causal organisms are of fundamental importance. With bacteria these are generally readily accomplished with synthetic media of various types. In the case of diseases caused by some bacteria, many protozoa, and most filtrable viruses, the situation is somewhat different, the only commonly practical method of propagation of these infective agents having been until late years through artificial infection in susceptible animals.

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[33] By M. S. Shahan, veterinarian, Pathological Division, Bureau of Animal Industry.

Discoveries that the membranes of the normal chick embryo are favorable for the propagation of the filtrable viruses of fowl pox, vaccinia, and herpes labialis opened the way for great strides in artificial culture of filtrable viruses in general. Today, many formerly noncultivable infectious agents, including those causing the several pox diseases, lymphogranuloma of man, many diseases of fowls, vesicular stomatitis and infectious encephalomyelitis (sleeping sickness) of horses, psittacosis (parrot fever), Rocky Mountain spotted fever, bovine pleuropneumonia, and influenza of man and animals are being intensively studied in the chick embryo, its membranes, or the constituent fluids of the incubated egg. The resulting comparatively cheap and readily available source of the infective agents being studied has contributed more to the study of filtrable virus and protozoan diseases than perhaps any other one development since the identification of the causal agents themselves.

The use of embryos, membranes, or fluids permits in many cases the convenient production of much greater quantities of virus, at a greatly lessened cost, the end result being more potent, more concentrated, and more effective vaccines and serums. Also, the identification, classification, and detailed study of many diseases, which before were greatly impeded by lack of a ready means of cultivation of the causative agents, have made accelerated progress.

FEDERAL FOOD, DRUG, AND COSMETIC ACT IN RELATION TO EGGS AND EGG PRODUCTS[34]

Eggs and egg products are subject to the provisions of the Federal Food, Drug, and Cosmetic Act of 1938 when they enter interstate commerce or otherwise come within the jurisdiction of the act. They must meet the standards set up under its provisions (fig. 36).

In general, the law prohibits the sale of adulterated and misbranded foods. It requires that eggs and egg products be sound, wholesome, and edible and that their labeling be in no manner misleading. Under these requirements, all eggs about which there is any question of edibility should be removed from lots of eggs marketed in the shell. Eggs which have been subjected to incubation are regarded as inedible. Egg products should be prepared by breaking out only edible eggs, under sanitary conditions such that no decomposition or contamination with filth or harmful ingredients can occur.

Labels and Mandatory Statements

Crates or cartons of eggs and cans and containers of egg products must bear labeling giving the name and address of the manufacturer, packer, or distributor, and a statement of the quantity of contents, together with the common or usual name of the product. These mandatory statements should be made on the display panel or panels of the package, that is, the panel which represents the article to the purchaser for what it is. In large containers of liquid- or frozen-egg products, prominent printing of the required information on a tag securely fastened to the can in such fashion as to be readily seen will afford a satisfactory compliance with these requirements without resorting to labeling on the container itself.

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[34] By Henry A. Lepper, senior chemist, Food Division, Food and Drug Administration.

The quantity of contents on shell eggs may be declared in terms of dozens and on liquid, frozen, or dried products in terms of avoirdupois pounds and ounces.

Standards of identity have been promulgated under the law for liquid, frozen, and dried whole eggs and yolks. These products should conform to such standards. When egg products are mixed with other foods the label must bear a statement of the ingredients present. They should be listed in the order of predominance in the mixture.

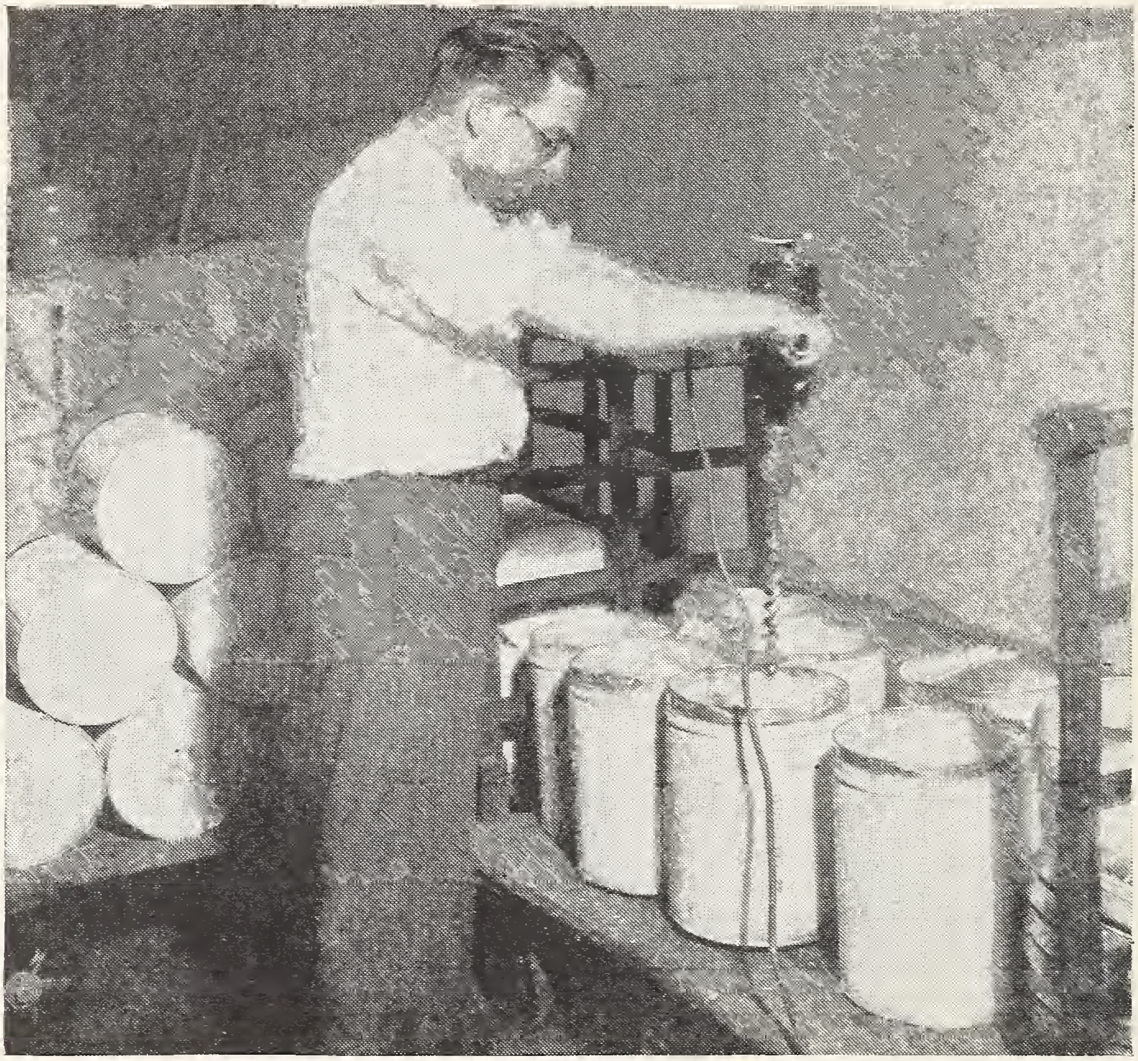

FIGURE 36.—Sampling cans of frozen eggs. Food and Drug Administration and State inspectors guard the quality of interstate shipments.

Decomposed, filthy, or otherwise contaminated eggs or egg products cannot be legalized by any expedient of labeling. They are subject by law to seizure and removal from the channels of trade. Food products that are inedible because of filth or decomposition can be removed from the application of the law only by treatment which will denature them as food. This fundamental principle has been upheld by judicial decision. A denaturing treatment must be chosen which will not interfere with industrial use of the product but will unquestionably prevent any food use. It usually involves the addition of a foreign substance that will contribute properties to the egg product so obviously objectionable to the senses as to prevent utilization of the egg material as food, either directly or in the preparation of other manufactured foods.

FEDERAL DEFINITIONS AND STANDARDS OF IDENTITY

Definitions and standards of identity of liquid, frozen, and dried eggs, mixtures and parts of eggs were established by executive order of Secretary of Agriculture Henry A. Wallace on July 19, 1939. The order became effective on January 1, 1940. These definitions and standards were determined at public hearings held by the Food and Drug Administration under provisions of the Federal Food, Drug, and Cosmetic Act.

No definition was established for the term "eggs," since in the orders that word is employed in its relationship to the manufactured product and not to eggs as laid. Up to the time of publication no standards have been promulgated for egg whites in liquid, frozen, or dried form. The following definitions have been published in the Federal Register:

Frozen yolks, or frozen egg yolks, are the food prepared by freezing yolks.

Dried egg yolks, or dried yolks, are the food prepared by drying egg yolks. They contain not less than 95 percent total egg solids, as determined by the method prescribed in Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, Fourth Edition, 1935, pages 297 and 298, under Total Solids.

Egg yolks, liquid egg yolks, yolks, or liquid yolks, are yolks of eggs of the domestic hen so separated from the whites thereof as to contain not less than 43 percent total egg solids, as determined by the method prescribed in Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, Fourth Edition, 1935, pages 297 and 298, under Total Solids. They may be mixed, or mixed and strained.

Dried eggs, or dried whole eggs, are the food prepared by drying liquid eggs. They may be powder. They contain not less than 92 percent total egg solids, as determined by the method prescribed in Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, Fourth Edition, 1935, pages 297 and 298, under Total Solids.

Liquid eggs, mixed eggs, liquid whole eggs, or mixed whole eggs, are eggs of the domestic hen, broken from the shells, and with yolks and whites in their natural proportions as so broken. They may be mixed, or mixed and strained.

Frozen eggs, frozen whole eggs, or frozen mixed eggs, are the food prepared by freezing liquid eggs.

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